FREE POSTERS!

+SIR DAVID ATTENBOROUGH

HOW IT WORKS

SCIENCE ENVIRONMENT TECHNOLOGY TRANSPORT SPACE

MEET COZMO
THE SMALL ROBOT WITH A BIG BRAIN!

LAST DAYS OF THE DINOSAURS

NEW EVIDENCE ON HOW AN APOCALYPTIC IMPACT WIPED OUT THE REPTILES THAT RULED THE WORLD

WHAT CAUSED THE EXTINCTION?

WHICH CREATURES SURVIVED?

WHAT HAVE SCIENTISTS DISCOVERED AT THE CRATER SITE?

LIFE IN DEATH VALLEY

The spring superblooms that take over the desert

RECORD-BREAKING WEATHER

From 160-day heatwaves to a tornado wider than a town

CULINARY CHEMISTRY

How chefs use science to create innovative dishes

THE FUTURE OF MEDICINE

The discoveries leading the fight against disease

HAPTIC TECH

Getting hands-on with the virtual world

MISSION TO MERCURY

EXPLORING THE SMALLEST PLANET IN THE SOLAR SYSTEM

Future
ISSUE 101
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ISSUE 101

WELCOME

The magazine that feeds minds!

"The El Reno tornado ballooned into a massive maelstrom of thunder and wind over four kilometres wide"

Record-breaking weather, page 64

Meet the team...

Charlie G
Production Editor
I've always really wanted to know exactly how the KT extinction wiped dinosaurs off the face of the Earth while sharks, crocs and even the platypus survived. Turn to page 14 to find out!

Charlie E
Staff Writer
I'm really excited to join the **HIW** team! My first feature takes a look at the life that somehow manages to flourish in the unforgiving Death Valley. Head over to page 70 to find out how it does it!

James
Research Editor
They may dig at a snail's pace, but the machines carving out the Crossrail network will help Londoners speed across the city like never before. Check out the epic engineering on page 40.

Duncan
Senior Art Editor
And I thought that British weather in the summer was bad enough! Take a look at the insane storms, biggest snowfalls and hottest conditions ever recorded over on page 64.

Laurie
Studio Designer
I think it's exciting to see how quickly medicine is progressing, tackling diseases that were once untreatable and changing lives. Turn to page 54 to find out more about the future of medicine.

FOLLOW US... How It Works magazine @HowItWorksmag

It's strange to think that if that asteroid hadn't struck Earth, we most likely wouldn't be here. Thanks to that impact, surviving mammals were able to fill some of the ecological niches left vacant when the dinosaurs died.

Recent research suggests that if the asteroid hit just a few seconds later, striking the ocean instead, the impact effects may not have been so destructive. It could well be that we owe our existence to just a few short moments. Discover more about the apocalyptic event and the most recent findings from the Chicxulub drilling project in our cover feature on page 14.

Half the world away from the Gulf of Mexico, there have been some surprising finds unearthed in London. While building the Crossrail network under one of the world's busiest cities, archeologists have excavated a range of objects, from prehistoric animal bones to Roman roads and plague pits! Find out more about the Crossrail project on page 40. We hope you enjoy the issue!

Jackie **Jackie Snowden**
Editor

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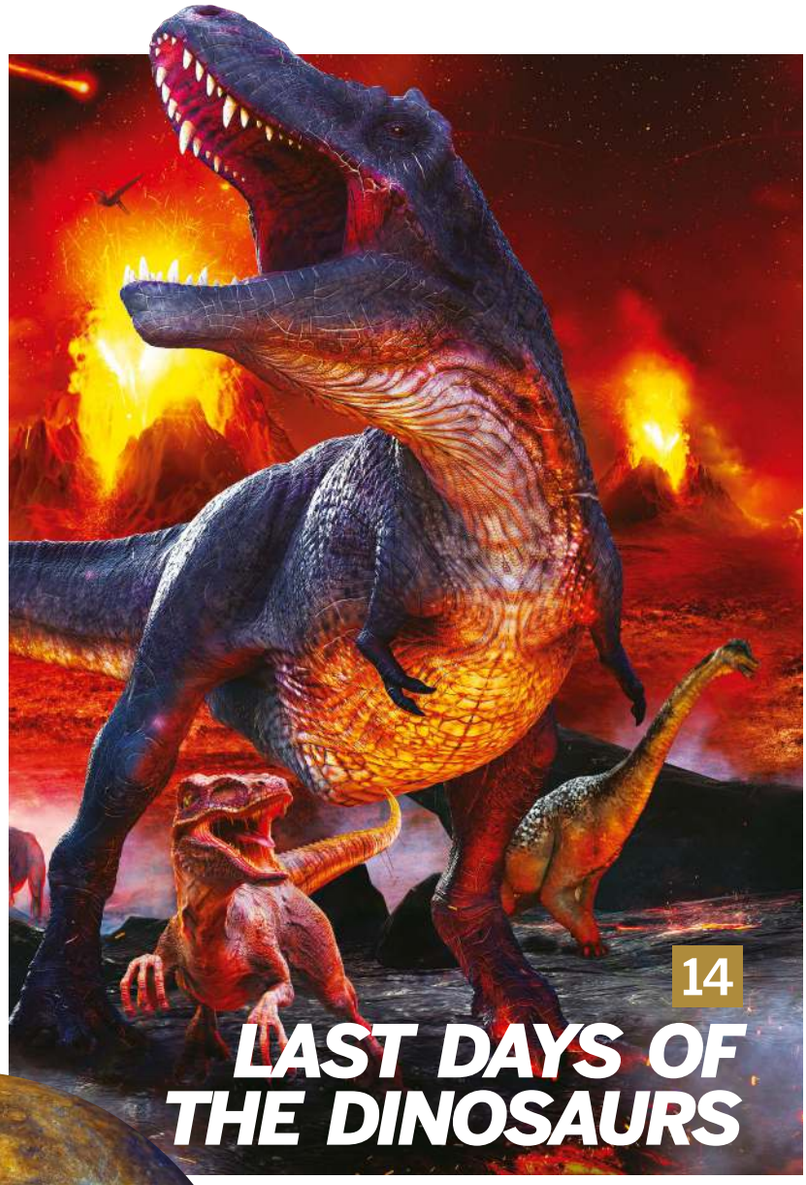

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Mission to Mercury

+ FREE POSTERS
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• EVERY SPACE MISSION
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Meet the experts...

Laura Mears
Laura brings us the latest research from the drilling project at Chicxulub to reveal how an asteroid impact and the catastrophic events that followed wiped the dinosaurs off the face of the Earth.

Mike Bedford
In our transport section, Mike goes behind the scenes at the epic Crossrail project to find out how engineers and mega machines are creating the new Elizabeth Line under one of the world's busiest cities.

Jonny O'Callaghan
Jonny explores the mysteries of Mercury and what this tiny planet can teach us about the Solar System. He also explains how to pick the perfect landing site on another world.

Mike Simpson
In our environment feature, Mike explains what causes mega tornadoes, high-speed hurricanes, half-year-long heatwaves and other extreme weather phenomena that have shattered records.

Becca Caddy
Science and tech writer Becca explains the amazing potential of haptics, from creating bionic limbs that can simulate a sense of touch, to providing us with VR experiences we can reach out and touch.

REGULARS

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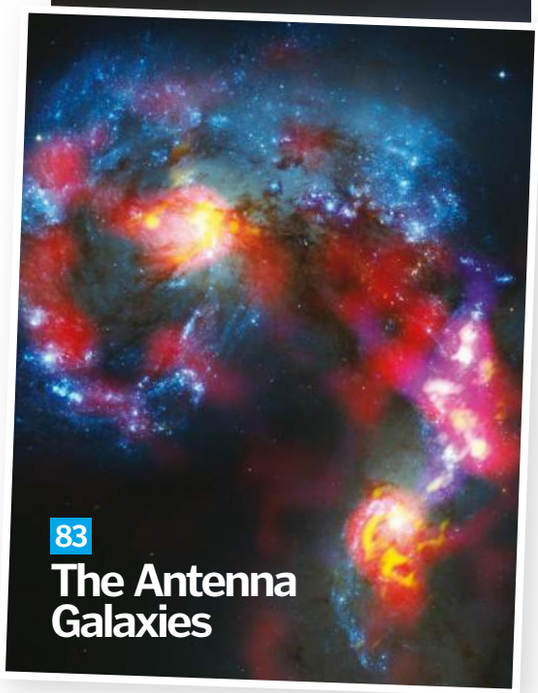

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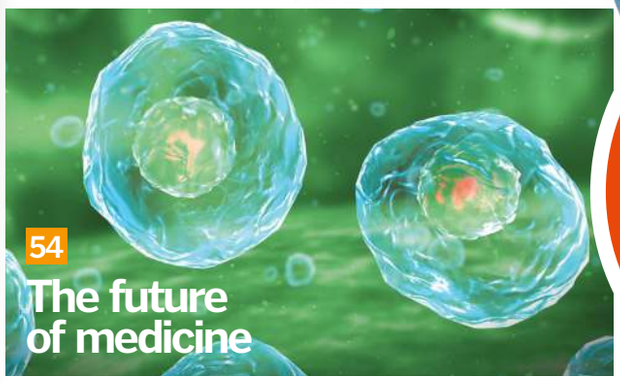


54 **The future of medicine**

The facility makes use of VR and AR technology to help train pilots and engineers

BAE Systems' state-of-the-art training facility opens

The new £2.3-million Training and Simulation Integration Facility combines gaming and Formula 1 technology to create an immersive environment for pilots

BAE Systems' TSIF in Warton, Lancashire, opened this month with the aim of transforming the future of military training and cockpit development. TSIF was developed in collaboration with Williams Advanced Engineering, who have applied innovative technologies derived from the world of Formula 1 to help create high-tech flight simulators. The Next-Generation Training Cockpit is a twin-seat cockpit simulator that can be reconfigured to replicate a range of training scenarios and jets, and allows trainees to test the latest human-machine interfaces.

The facility also includes an Augmented Reality Environment, harnessing virtual and augmented reality for engineers and pilots to test their aircraft maintenance and training in a fully-immersive, 3D environment. A Classroom of the Future aims to enhance the learning experience and reduce reliance on expensive physical tools by allowing students to tour the body of an aircraft with wall-to-wall interactive displays and synthetic training aids. Pilots and engineers can also train together in the Networked Synthetic Environment, a suite of high-speed desktop simulators for several aircraft types, such as the Hawk and the Typhoon, and different mission scenarios.

Steve Timms, managing director of Defence Information, Training & Services at BAE Systems, said, "This new facility represents a fresh blueprint for the future training of pilots and engineers. Such an innovative application of virtual reality and simulation technologies offers a wealth of advanced, more affordable techniques for the training of teams on the maintenance and design of advanced fast jets – and this is just the beginning of possible applications for that technology in the sector."

"The Next-Generation Training Cockpit can be reconfigured to replicate a range of training scenarios"

TSIF is part of a wider project by BAE Systems to invest £10 million in training and simulation facilities at Warton

Training and Simulation Integration Facility

An innovative environment for the design and development of air platforms and next generation training

This unique facility provides a collaborative space for engineers, operators and customers to share ideas and exploit the latest technologies for use in current and future military products and services.

1. Typhoon cockpit
Pilots and engineers can trial upgrades to the Flight Control System in an immersive and realistic simulated environment.

2. Next Generation Cockpit
A twin seat cockpit designed in collaboration with Williams Advanced Engineering. Interactive cockpit displays mean it can be configured to represent different aircraft including Hawk, Typhoon and other future cockpit concepts.

3. Simulation Control Room
A central hub to control and monitor complex live simulated trials between networked devices.

4. Classroom of the future
Students can virtually tour through an aircraft using wall to wall interactive displays.

5. Desktop training devices
Featuring multiple platform training devices which can be networked to support large scale synthetic training exercises.

6. Augmented Reality lab
Virtual and augmented reality devices from the gaming world are used to create a 3D experience to walk through and around aircraft as well as developing the design of future cockpit concepts.

BAE SYSTEMS
INSPIRED WORK

EMPATHY GENES IDENTIFIED

Our DNA can determine how well we can read other peoples' emotions through their expressions

Empathy enables us to recognise and understand other people's emotions

The largest study of its kind is attempting to determine the relationship between the performance on a cognitive empathy test and genetics. The results suggest that our DNA is at least partly responsible for our ability to understand a person's thoughts and emotions by looking at the expression in their eyes.

A team of scientists working with the genetics company 23andMe have identified a genetic variant on chromosome 3 to positively correlate with the ability to 'read' eyes. The study on 89,000 people across the world used a test known as the Eyes Test to determine individuals' cognitive empathy ability.

This small part of chromosome 3 includes the gene LRRN1 (Leucine Rich Neuronal 1) that has been previously identified as playing a large role in the striatum. This area of the brain is known to play a role in empathy, and the new study seems to suggest that the same genetic variation that correlates with higher scores on the Eyes Test also increases the volume of the striatum.

This is an important step forward for the field of social neuroscience and adds one more piece to the puzzle of what may cause variation in cognitive empathy. This research supports the theory that empathy is determined by genetics in addition to experiences in childhood.

The team will continue to investigate the subject in detail and intend to further explore the function of these genetic variants and how they are responsible for differences in cognitive empathy ability.

What does the striatum do?

FMRI and neurophysiological studies have suggested that the striatum operates around social actions and social rewards, making it vital for successful social interaction, such as learning about another person's likes and dislikes. This part of your brain is also the part that is active when you are controlling your impulses and attention span, and dysfunctions in this area of the brain have been associated with addiction, depression and obsessive-compulsive disorder.

The striatum is one of the central parts of the forebrain

NEWS BY NUMBERS

391.73 million
The average number of gallons of petrol used each day in the US

10,000-25,000
The estimated population of blue whales

2,483
The number of confirmed planets that the Kepler space telescope has discovered

300,000 years
The age of the oldest Homo sapien remains ever discovered

Embryonic stem cells are able to transform into any of the cell types in our bodies

World's first embryonic human stem cell clinical trials to begin

Trials in humans are about to start to treat Parkinson's and age-related blindness

Two medical teams in Zhengzhou, China, will be pioneering stem cell research by carrying out the world's first human embryonic stem cell trials. One team will be injecting approximately 4 million embryonic neuronal cells into the brains of Parkinson's patients, and the other will be starting trials using the cells in the hopes of replacing retinal cells in macular degeneration caused blindness.

The stem cells act like blank canvasses with no specific function but can be 'differentiated' into any cell type that exists in your body. It is hoped that the stem cells will be able to repair the damage of Parkinson's by replacing the lost neurons in the brain, while the trials on macular degeneration are relying on the stem cells to differentiate into surface cells at the back of the eye on the light-catching retinal pigment epithelium.

More and more companies are investing in the development of driverless cars

Apple are working on autonomous driving technology

Tim Cook, Apple's chief executive, has confirmed the company is developing a system for a self-driving car

One of Apple's top executives has openly confirmed plans to branch out into the car industry. Cook has suggested it is too early to comment whether Apple will license the tech to other carmakers or will be producing their own vehicles, but they have announced that they are focusing on autonomous systems and consider this aspect a core technology.

Scientists discover new antibiotic to treat drug-resistant bacteria

Pseudouridimycin has been found to kill a range of drug-resistant bacteria in the lab

A recent paper published in the scientific journal *Cell* has reported the discovery of a new antibiotic that has proved effective within a laboratory. Scientists have so far managed to successfully treat bacterial infections in mice. The antibiotic, named pseudouridimycin, is produced by a microbe that was found in a soil sample in Italy. The discovery could help in the fight against the highly concerning rise of antibiotic resistance.

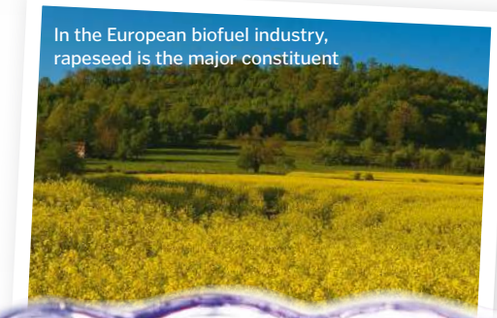
NEW PROCESS MAKES BIOFUELS MORE PRACTICAL

A refining method enables biofuel to be used in standard diesel car engines by taking advantage of catalysts

It is established that plant-based fuel is a more eco-friendly alternative than fossil fuels. However, this invention has faced many challenges due to the molecular composition of the fuels. The chemical differences between fossil fuels and biofuels mean they boil at different temperatures, so biofuel requires specially designed engines to be built. It can be argued that this is one of the biggest barriers to widespread use of biofuels.

Conventional biodiesel is unable to be used in standard diesel engines because around 95 per cent of its molecular chains are the same length, meaning they boil at approximately the same temperature. There is an increasing pressure to create a replacement for fossil fuel using systems and technology that are already in place.

German scientists have just invented a new method to treat plant chemicals to create a biodiesel that meets the European Committee for Standardisation criteria required for commercial diesel sold within the EU. The process involves catalysts. The catalyst means that it is possible to process biodiesel at a lower temperature but using less energy than any other method. This means a higher yield of fuel and drives the production costs down.



In the European biofuel industry, rapeseed is the major constituent

Producing biodiesel

Biodiesel production is a new technology that has arisen from the need to reduce our carbon emissions from fossil fuels. The process involves mixing vegetable or animal oils with short-chain alcohols such as methanol or ethanol. The oils are primarily obtained from oil crops such as palm or soybean, and most biodiesels created today are from waste from industrial food producers. Biodiesel is carbon neutral, biodegradable and non-toxic, meaning that any spillages are much less damaging to the environment.

Biodiesel production is still in the process of being perfected and faces many challenges before it can enter widespread use

Biodiesel production from algae is more efficient than other methods

"I wanted to do something more human, which led me to coal mining"

Q&A Public Service Broadcasting

We chatted to J Willgoose, Esq from PSB to talk about the inspiration and technology behind the band's latest album

It is really interesting how you use the old public service announcements and archives. Where did that idea come from? And how do you decide what to include?
There is always sort of a rough idea – even going back to the days of *Signal 30*, we thought it would be fun to use some of these over-the-top driving safety films and write a fast, aggressive song that is good to drive to. So then you are instantly narrowing your search down and looking for things – looking for the most ridiculous sounds bites to put into a song. With the new album it was much more like setting a framework for a documentary from start to finish. It was the story – where you want to start, where you want to finish and how you are going to get there – and that was much more work, trying to go in search of samples to fulfil that role. Normally, I'd say it is 50/50 working with samples and working with music. This time it is heavily music, and then looking for the samples to drop in.

How do you perform the tracks live?
I like stability in a live set up, and I think the less the computer is doing the better. Previously the computer was doing a lot; because of all the looping, we were running the guitars through the computers, but for boring reasons that make it a little bit harder to play because there is a slight latency on it, and it also increases the load on the computer. We have had a couple of vanishing acts where we have had to turn to backup, so I've been unhappy with it for a while. There is some new technology that we use while recording this album that allows you to capture the sound of an amp through the microphone you recorded it through – so you should, in theory, get the exact sound that you had on the album for every song, live. That's a little unit called a Kemper Profiler. It's just been a lot of work, but it sounds a lot better and it's more fun to play, so I think it's going to be worth it in the long term.

Your previous record revolved around the Space Race. Are there any other themes you would like to explore?
The new album is taking a new turn really. We had made an EP about World War II [*The War Room*], and covered a lot of grand subjects on our first album. For *The Race For Space*, you don't get much bigger topics than that really. I wanted to do something more human than that, more kind of tightly focused, which led me to do coal mining in South Wales, with the history and death of the industry and what it has done to communities there.

Is that something that you have personal ties with?
No, nothing like that. I just thought it was an interesting story, it was a good place for us to go next so we don't just keep making the same kind of records, time after time. I think it was a harder sell – it's not as glamorous or exciting. In a way that makes it more interesting and a more difficult songwriting challenge – how do you take a subject that might turn some people off and make it exciting and accessible? That was the idea behind this record, as well as really making something that actually said something about our history and society, and made a quiet political statement – hopefully a powerful one.

Public Service Broadcasting's new album, *Every Valley*, is out now

GLOBAL EYE

10 COOL THINGS WE LEARNED THIS MONTH

1 There is an Earth-like planet orbiting a nearby star

A new Earth-like exoplanet has been discovered orbiting a red dwarf star just 21 light years away from us. The planet, named GJ 625, is located at the edge of its star's habitability zone and astrophysicists have said that it is 'potentially habitable' depending on its cloud coverage and rotation. Scientists at the institute will be attempting to determine the planet's density, radius and atmospheric conditions when it passes in front of its star.

This small rodent is more closely related to elephants than shrews

The sengi is the world's fastest small mammal and can be found all across Africa living in grassland, jungles, and savannas. They are just a few inches long and despite looking like a shrew they are genetically more similar to elephants. Their unique nose can twist and turn and be used like a trunk to search for food.

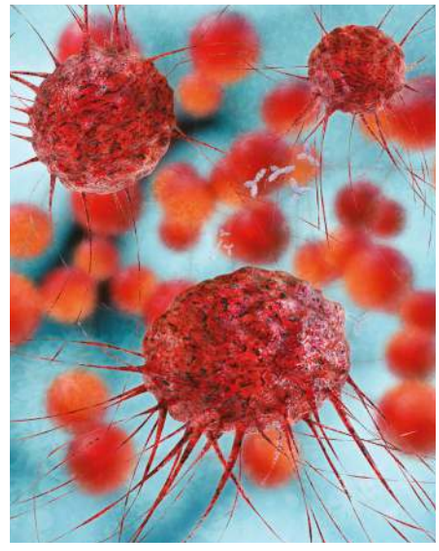
3

2 Human skin can be 3D printed

3D printing is revolutionising regenerative medicine. Pioneering the field is the emergence of 3D-printed, plasma-based human skin using bio-inks. The process creates an outer protective epidermis before printing another layer for the thicker dermis and layering them to replicate the natural structure of the skin. The technology could prove revolutionary in treating burn patients and individuals with surgical wounds.

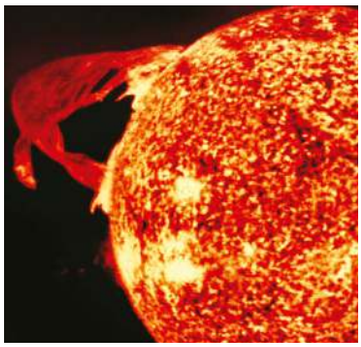
4 Gold nanoparticles are a promising cancer treatment

Clinical trials using nanoparticles have demonstrated the effectiveness of gold as a cancer treatment. Gold nanoparticles are coated with antibodies so that they can recognise cancerous cells. The cells can then be treated with a laser pulse that heats up clusters of the nanoparticles, which have accumulated only amongst the diseased cells. The groups affected by the intense heat are destroyed, removing the cancer cells but leaving the nearby healthy cells unharmed.



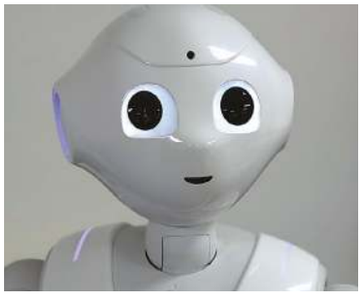
5 Old antibiotics can be re-engineered

Scientists have redesigned vancomycin after bacteria had evolved resistance to the old antibiotic, which has been in use for more than 50 years. By editing the molecular structure, it has been provided with three additional mechanisms to kill bacteria including an increased ability to destroy bacterial cell walls. These extra mechanisms will act as barriers to slow down resistance to the new vancomycin in the future.



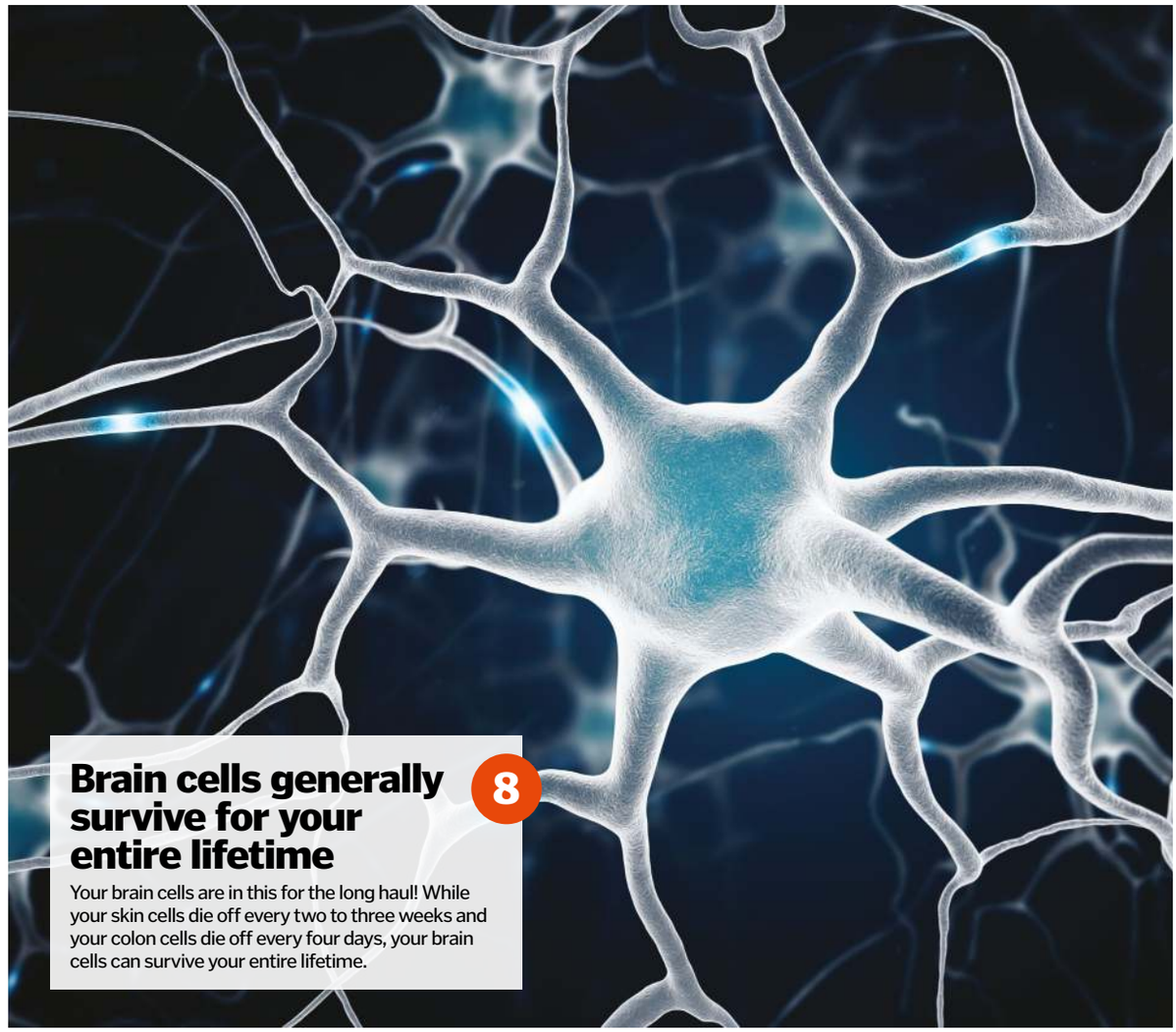
6 NASA want to touch the Sun

NASA's Parker Solar Probe will be launched in July 2018. An 11.5cm-thick carbon composite heat shield has been built to keep the probe cool while the heat on the outside of the vessel soars to 1,400°C. Over seven years, the solar-powered probe will loop around Venus seven times, moving closer towards the Sun with each orbit, eventually sweeping within 6mn km of our star.



7 A humanoid robot has been designed to assist the elderly

Rice University are developing a Multi-Purpose Eldercare Robot Assistant (MERA) to keep senior citizens safe – particularly people who are living alone. The robot will be able to read vital signs and monitor changes in scent, audio or motion in order to determine if there has been an incident such as a fall or a fire.

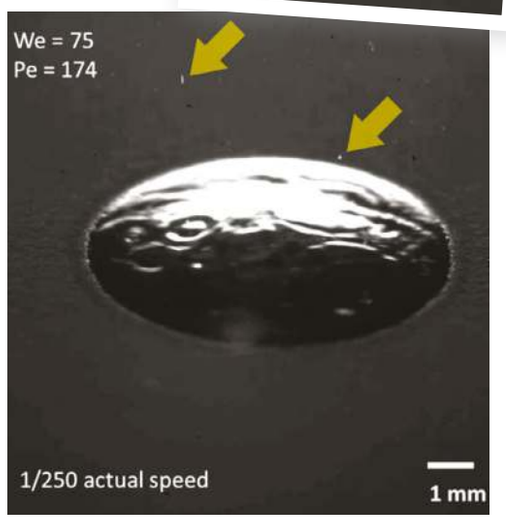


8 Brain cells generally survive for your entire lifetime

Your brain cells are in this for the long haul! While your skin cells die off every two to three weeks and your colon cells die off every four days, your brain cells can survive your entire lifetime.

9 The smell of freshly fallen rain is caused by bacteria

The technical term for the fresh earthy smell after a light rain is called 'petrichor'. It is caused by tiny bubbles forming in raindrops when they land. The bubbles then rise up through the rain drop and pop like bubbles in a fizzy drink, thereby releasing the microbes that have been lying dormant on the dry ground.



10 A new trial will be editing viruses inside the body

CRISPR technology allows genes to be inserted, changed or deleted from a genome in a faster and more efficient way than ever before. Human trials in China are set to take the technology one step further by attempting to edit cells already inside the body. The trials will be applying a gel filled with DNA coding for CRISPR machinery to the cervix of participants in the hopes that the virulent genes inside the virus will be destroyed.

LAST DAYS OF THE DINOSA

URS

How did an entire tribe of giant reptiles disappear from the face of the Earth?

In 1677, English naturalist Robert Plot came face-to-face with a thigh bone belonging to an animal one and a half times his height. He thought the monstrous femur belonged to a giant. Since then, enormous bones have shown up in rocks around the world, but the creatures that they belonged to are nowhere to be seen.

From the spike-thumbed iguanodons of England to the feathered microraptors of China and the iconic tyrannosaurs of the United States, dinosaurs ruled every corner of our planet, but between 66-64 million years ago they completely disappeared. The so-called KT extinction marks the transition between the Cretaceous and Tertiary periods of geological history.

During this catastrophic period, almost three-quarters of life on Earth withered away. Ammonites and belemnites disappeared from the oceans, along with dozens of species of nanoplankton, two entire groups of clams and many of the relatives of modern starfish, sea urchins, brittle stars and sea cucumbers. The ocean's top predators, the mosasaurs, also vanished. Winged pterosaurs went missing from the skies, and flowering plants died in their thousands, leaving behind a landscape dominated by ferns.

In 1980, Nobel Prize-winning American physicist, Luis Alvarez, and his son Walter noticed something unusual in the geological record. At around the time of the KT extinction, there was a band of the brittle, white transition metal, iridium. Usually rarer than gold, spikes of this unusual element appear in more than 100 places across the globe. The most likely explanation was an asteroid impact.

Iridium might be rare on our planet, but it's common in space rock. If an asteroid had collided with Earth, it could have kicked the metal into the atmosphere. As the dust settled, this would have formed a band in the rocks, marking the time of the impact.

At the level of this band there is also evidence of shocked quartz; a type of rock with distinctive microscopic features that form under intense pressure. There are also spheres of glass, made when molten rock is thrown up into the atmosphere and solidifies before it falls back to the ground. And there are vast quantities of soot, which could signal large-scale forest fires caused by burning debris from an extraterrestrial impact. Traces of the asteroid are greatest in North America. In Haiti there is a thick band of clay filled with glass spheres, and in the Gulf of Mexico tumbled rocks hint at an enormous tsunami, which could have been caused by an asteroid slamming into the planet.

To cause this level of destruction, the asteroid would have had to have been more than ten kilometres wide and travelling so fast that it

would have gouged a 100-kilometre-wide hole in the surface of the planet. It should have left an enormous crater, but the impact site was nowhere to be seen, and not everyone was convinced by the theory.

Earth was already undergoing a climate crisis; sea temperatures were rocking up and down, and water levels were rising and receding. What's more, asteroids aren't the only source of iridium, and extraterrestrial impacts aren't the only way that ash gets into the atmosphere. Even shocked quartz and glass spheres can be made by something other than an asteroid. All of these features could also be explained by volcanoes, and around the time the dinosaurs disappeared, there were some monumental eruptions.

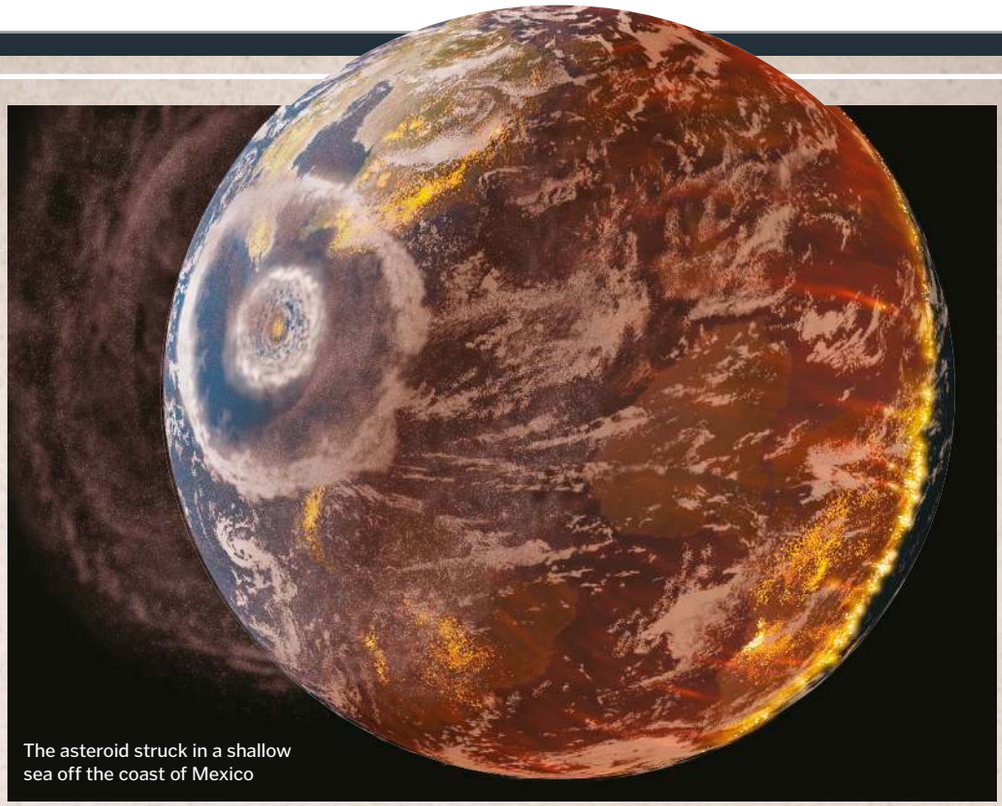
At that time, India was an island sitting on top of a volcanic hot spot. Bubbles of hot rock were rising from the Earth's mantle, which, unlike the crust, contains high levels of iridium. The magma poured out onto the surface, depositing more than 1 million cubic metres of new rock and forming vast lava plains now known as the Deccan Traps. As this happened, ash, sulphur and metal would have billowed and plumed into the air, potentially blocking out sunlight.

Both sides claimed the same evidence for their explanation of the trigger that caused the dinosaurs' demise, and without an actual impact crater, the Alvarez hypothesis had some gaps, but in 1990 geoscientist Alan Hildebrand found the smoking gun. Buried in a shallow sea off the coast of Mexico, there was a 180-kilometre-wide hole with strange gravity and an unusual magnetic field. It contained igneous rock, shocked quartz, spheres of glass and breccias – structures made from crushed rock glued together by mineral cement. It looked like the debris of an asteroid impact.

From the shape of the crater, it appears the asteroid came in at an angle, skidding debris up towards North America. The rock would have been fractured by intense vibrations, shooting molten debris into the air, and the thermal shock would have been so intense that everything within sight of the impact would have been totally obliterated.

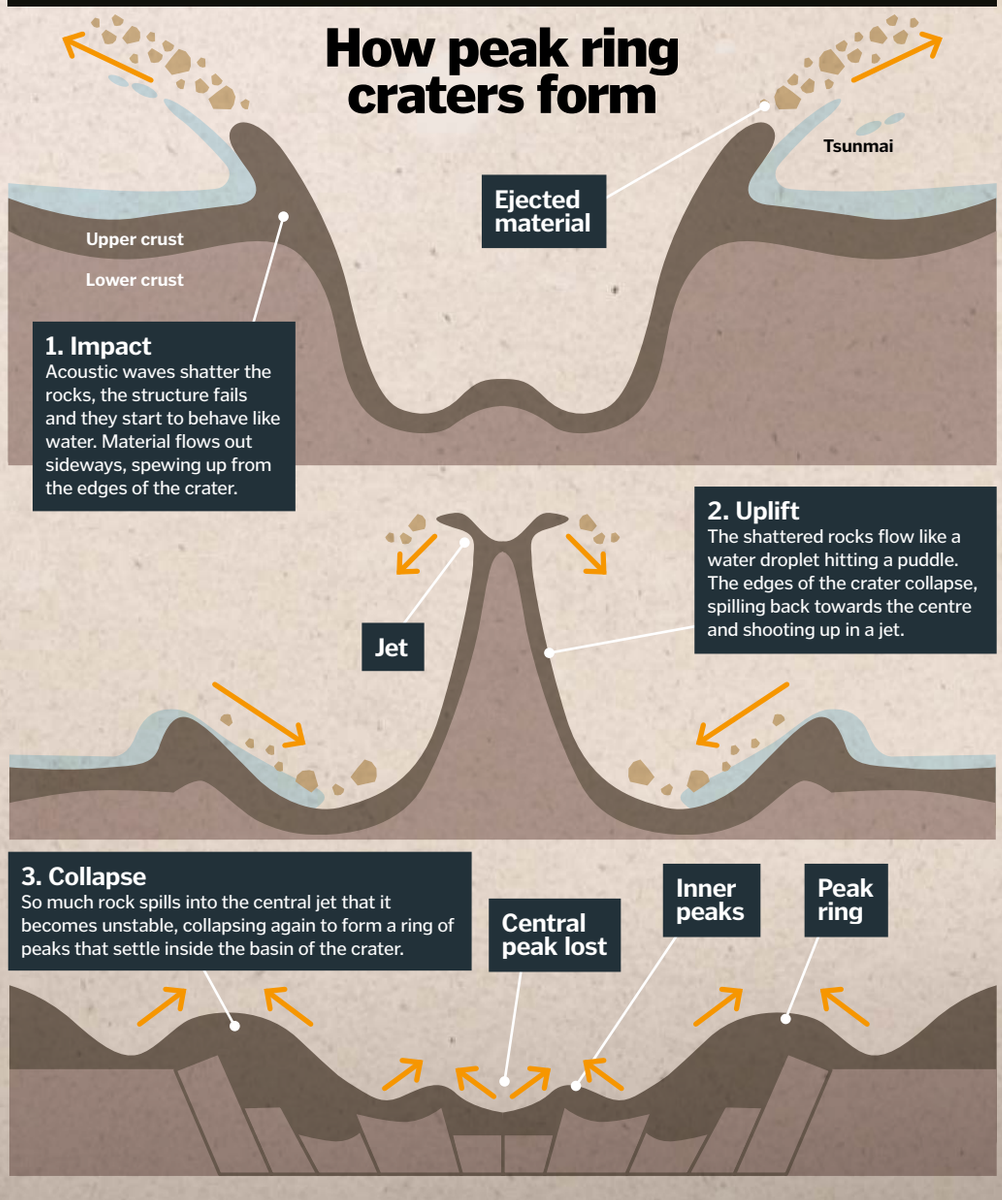
What followed would have been an earthquake of a magnitude unmatched by even the most powerful in recorded history. Vast tsunami waves would have been hurled across the oceans and debris from the impact site would have shot up with such force that some escaped the atmosphere. As the jettisoned rocks returned they would have burnt up, raining fire across the ground. Plants and animals in the surrounding area would have died instantly or within a matter of days.

Later, as fragments of ash, sulphur and soot from burning forests clogged the air, the world



The asteroid struck in a shallow sea off the coast of Mexico

How peak ring craters form



An extinction in numbers

10km
THE SIZE OF THE ASTEROID

180km
THE WIDTH OF THE CHICXULUB CRATER

65-66 million
THE NUMBER OF YEARS THAT HAVE PASSED SINCE THE IMPACT

11
THE MAGNITUDE OF THE EARTHQUAKE THAT WOULD HAVE SHAKEN EARTH AFTER THE IMPACT

BIGGEST RECORDED QUAKES COMPARED

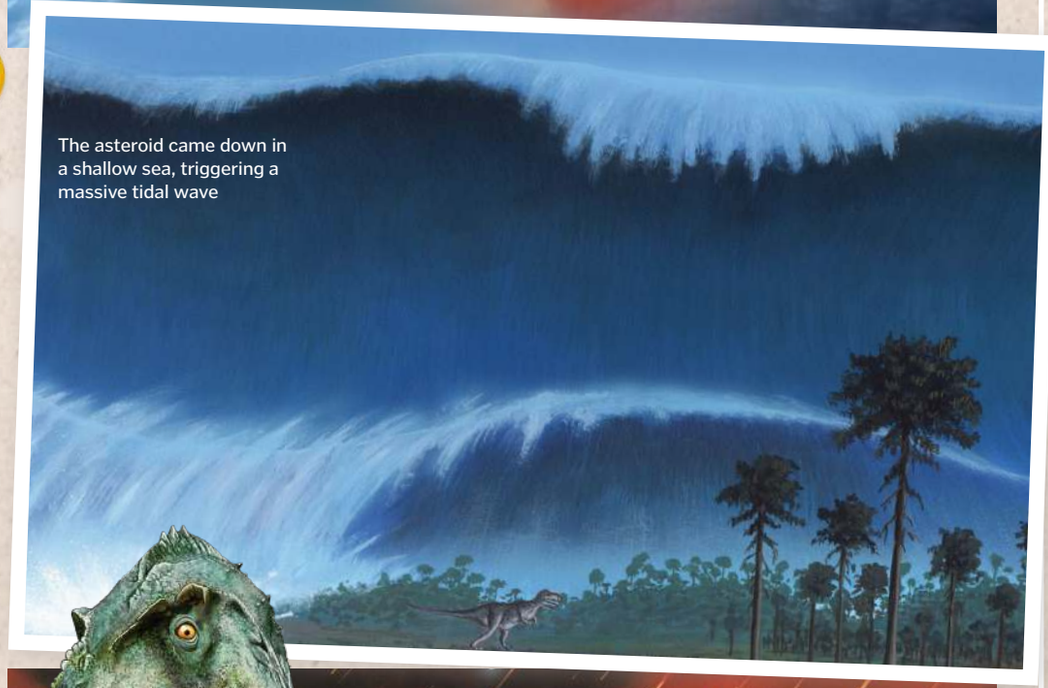
9.5 VALDIVIA, CHILE, 1990
9.2 PRINCE WILLIAM SOUND, ALASKA, 1964
9.1 SUMATRA, INDONESIA, 2004
9.1 SENDAI, JAPAN, 2011
9.0 KAMCHATKA, RUSSIA, 1952

70%
THE ESTIMATED PROPORTION OF SPECIES WIPED OUT BY THE IMPACT

10 degrees
THE RISE IN GLOBAL TEMPERATURE FOLLOWING THE IMPACT

100 million megatons
THE BLAST FORCE OF THE IMPACT

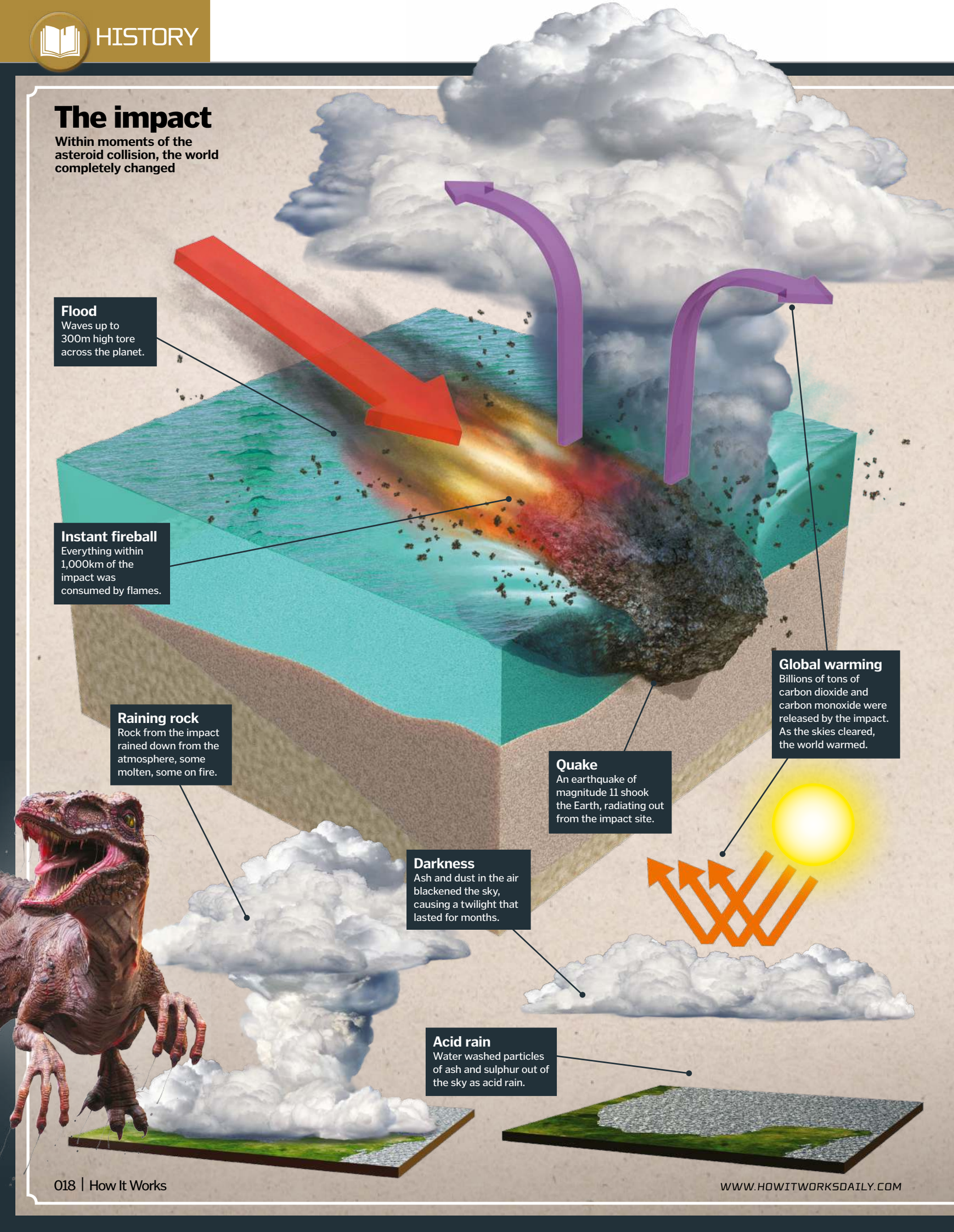

The impact shot spheres of molten glass into the air


The asteroid came down in a shallow sea, triggering a massive tidal wave


Glass and rock rained from the sky over North America

The impact

Within moments of the asteroid collision, the world completely changed



would have been plunged into perpetual twilight for weeks or even months. This 'impact winter' would have hit photosynthesisers hard, knocking out plankton in the seas and plants on land. With the bottom falling out of the food chain, entire ecosystems would have started to feel the strain.

The dust poured out of the sky as acid rain, but the ordeal was not yet over. The Chicxulub crater, as it is now known, sits right in the middle of a three-kilometre-thick layer of carbonate rock. It acts as solid storage for greenhouse gases like carbon dioxide, and when struck, it could have sent temperatures spiralling. As the air finally cleared, billions of tons of these greenhouse gases would have triggered rampant global warming.

As Hildebrand said at the time of the discovery: "The Chicxulub impact, having presumably produced the largest impact crater on Earth, would have caused a mass extinction."

But even with the crater identified, some people still have their doubts. The most complete fossil record comes from North America, but even so, it's hard to create an exact timeline. Rock that old can't be carbon-dated, so it's not easy to tell if the dinosaurs all died at once, or if the extinction happened gradually. And not all species were preserved, so it's hard to piece together the ecosystem in enough detail to understand what caused it to fall apart. Specific conditions are needed to preserve the bones of fallen animals, and many perished without a trace.

Although there is good evidence that an asteroid did strike at Chicxulub, whether it killed the dinosaurs is hard to confirm. Some scientists argue that the impact happened about 300,000 years before the mass extinction, because some of the fossil evidence sits in layers of sediment above the impact line. It's possible that this chunk of sediment was thrown on top of the rocks by tsunamis triggered by the asteroid, but it's also possible that the sediment was laid

Incineration
Everything in the surrounding area was charred by an enormous fireball.

Darkness falls
The debris blocked out sunlight, plunging the Earth into a lengthy period of darkness.

Resurgence
As the dust cleared, surviving seeds and spores started to grow and animals emerged.

"With smoke from burning forests filling the air, the world was plunged into twilight"

What a difference a moment makes

The Chicxulub crater sits just off the coast of Mexico, in a shallow sea where the sediment was once filled with carbon and sulphur. When the asteroid struck, this rock shot into the atmosphere. 100 billion tons of sulphate particles and carbon – in the form of carbon dioxide, carbon monoxide and methane – entered the air. The sulphate first reflected the light, cooling the planet, but when it washed out of the sky as acid rain the carbon turned the atmosphere into a greenhouse and global temperatures climbed by degrees.

But a BBC documentary recently revealed that if the impact had come just seconds later, the rock would likely have settled in the depths of the ocean. Tsunami waves would still have flooded the surface, but the killer sulphur and greenhouse gases might never have entered the atmosphere and the dinosaurs may have been spared.

If the asteroid had come down in the deep ocean, the dinosaurs might have survived

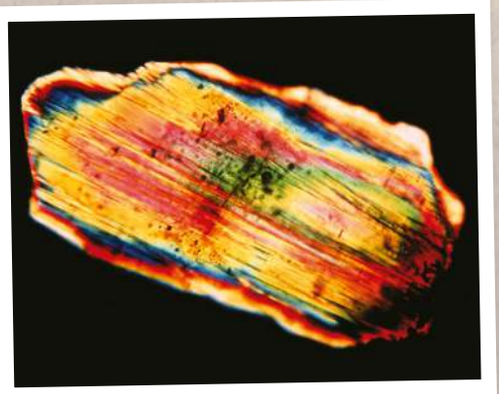
down gradually and that the extinction of the dinosaurs wasn't as rapid as it might first appear. There's evidence that animals burrowed into the soft rock and there's erosion that looks like it was created by flowing water.

To dig deeper into the role of Chicxulub in the last days of the dinosaurs, scientists have been drilling into the remains of the impact site. Chicxulub is the largest impact crater on Earth. The asteroid that caused this hole was so big that it created a distinctive ring of molten and fragmented rock inside the outline of the crater – the so-called 'peak ring'. Since the impact the crater has been buried in 17 metres of water and 500 metres of limestone.

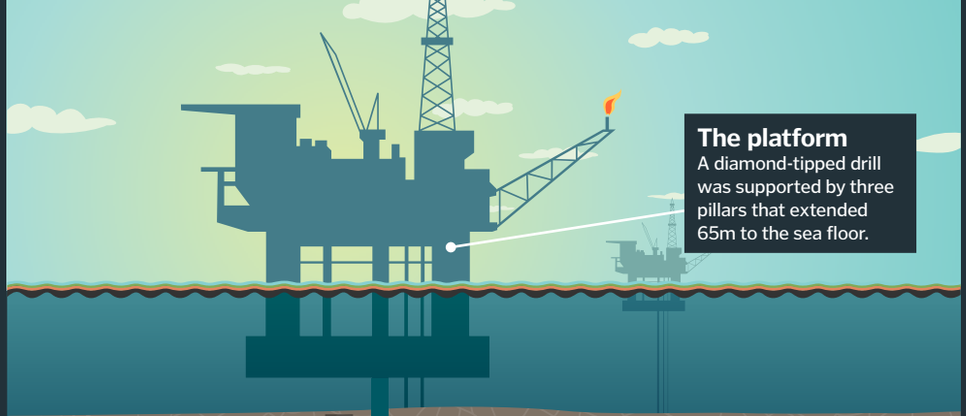
Between 2001 and 2002, the International Continental Drilling Program piled into the structure from the land in Mexico, revealing rock known as 'impact melt' that was likely made from fragments of rock that were shattered, spewed and then glued together when the crater formed. The drills also revealed evidence of hydrothermal activity caused by the huge impact, hinting that steam might have vented onto the crater for more than a million years after the asteroid struck.

In 2016, using a diamond-tipped drill, scientists bored into the structure again, this time targeting the peak ring to find out how it was formed and what happened in the aftermath. One startling discovery was the presence of pink granite in their drill samples. This crustal rock should have been down at a depth of 7,600 metres, but it turned up at 760 metres, evidence of the intense shock that crumpled and shook the Earth below.

There are still many unanswered questions about the extinction of the dinosaurs, and the reality is that we won't ever know the truth of what happened for sure. The Chicxulub crater is thought to have spawned one of the most devastating extinction events of all time, but evidence being gathered from the remains of the crater hint that impacts can nurture life as well as destroy it.



The stress lines inside shocked quartz are caused by intense pressure



The platform
A diamond-tipped drill was supported by three pillars that extended 65m to the sea floor.

DRILLING FOR CLUES

Scientists are collecting rock samples from Chicxulub crater to try and answer Earth's biggest questions

150m
300m
450m
600m
750m
900m
1,050m
1,200m
1,350m
1,500m

Sediment
To reach the impact crater, the drill first had to get through over 450m of sediment, laid down since the impact.

Thermal maximum
At 550m the rock dates back 55 million years. Earth was warmer then, revealing the remains of algal blooms.

Recovery
Between 550 and 610m, the rocks showed life returning after the impact, including limestone filled with fossils.

Ground zero
The chunk between 610 and 800m represents ground zero, filled with shocked quartz and sandy deposits left over from the colossal tsunami waves.

Peak ring
The drill reached the peak ring in 2016. It contained granite above shocked quartz, supporting the peak ring formation theory.

The drill rig is raised up above the sea to create a stable platform

Not only did the KT extinction make way for the rise of mammals; the most recent drilling expedition revealed a large network of channels that were filled with warm water after the impact. At first they would have been too hot for even the hardiest of life forms, but as they cooled, microscopic life could have thrived in the warm, damp cracks, nourished by minerals leaching out of the rocks. And this has exciting implications for the origins of all living things.

Though life was already firmly established by the time the Chicxulub asteroid arrived, the crater gives us a glimpse into the kinds of conditions that might have been present on the ancient, lifeless Earth. Charles Darwin thought that life might have begun in a "warm little pond", where minerals mixed with water and organic molecules. Asteroids are stuffed with organic compounds that could have provided the ingredients for the chemistry life to begin, and if they set up warm, wet, mineral-rich niches when they strike the Earth, they could be the parents of Darwin's little ponds.

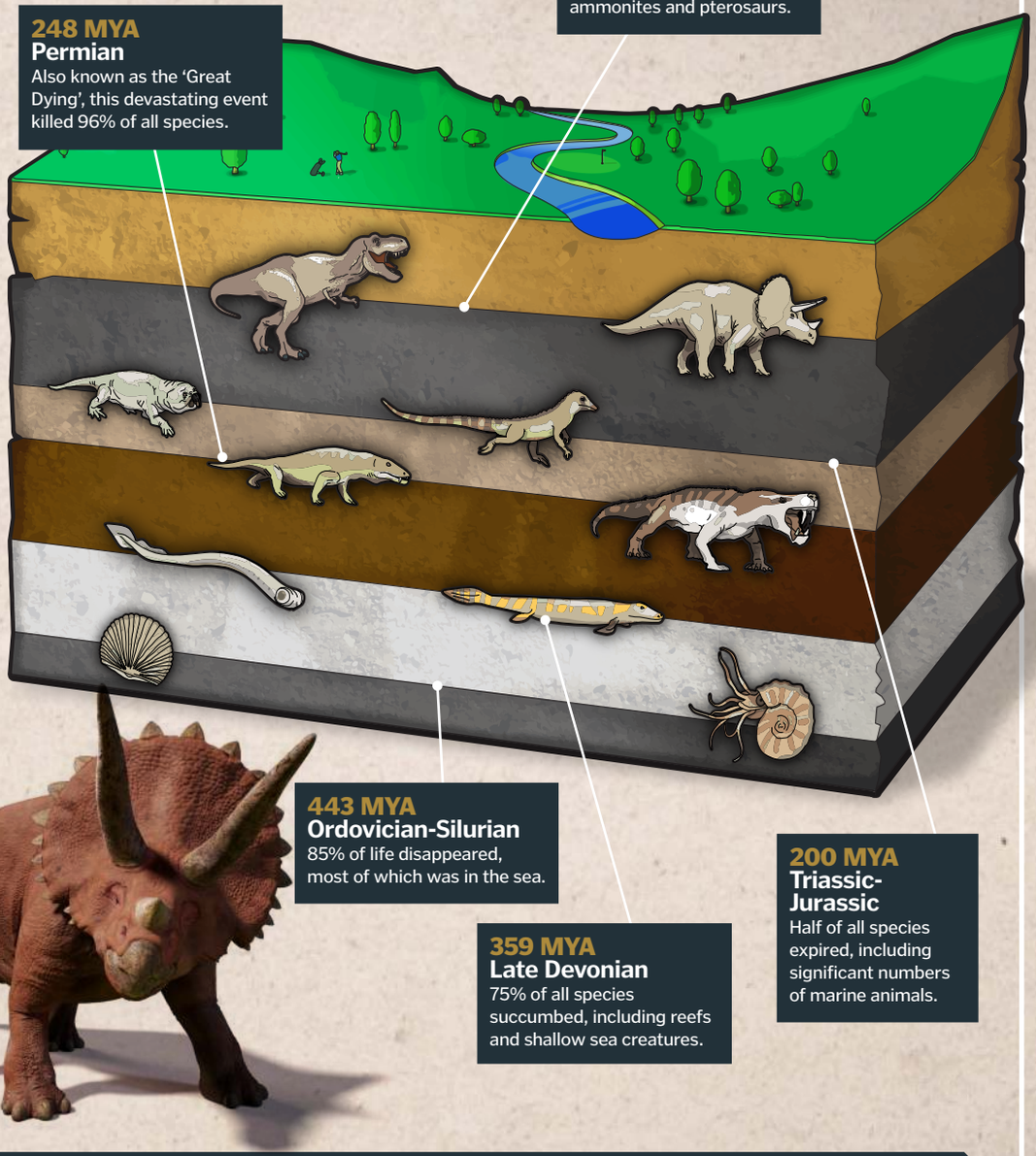
As we speak, NASA's OSIRIS-REx is hunting the asteroid Bennu (which scientists have suggested could collide with Earth in the 22nd century) in search of clues as to whether asteroids could have helped life to begin on Earth billions of years before the dinosaurs even existed.

While it is unlikely that we will ever know exactly how the dinosaurs died, their demise might shed light on an even bigger question – how did they get here in the first place?

"Microbes may have thrived, nourished by minerals leaching out of the rocks"

Mass extinctions

The KT extinction was not the first and it won't be the last



66 MYA
Cretaceous-Tertiary
70% of species were killed, including dinosaurs, ammonites and pterosaurs.

248 MYA
Permian
Also known as the 'Great Dying', this devastating event killed 96% of all species.

443 MYA
Ordovician-Silurian
85% of life disappeared, most of which was in the sea.

359 MYA
Late Devonian
75% of all species succumbed, including reefs and shallow sea creatures.

200 MYA
Triassic-Jurassic
Half of all species expired, including significant numbers of marine animals.

Making way for mammals

The KT extinction event devastated the Earth, but without it, we wouldn't be here today. As the dominant land animals struggled to survive in a world charred by debris, blackened by sulphur and soot and heated by greenhouse gases, tiny mammals were shielded in their burrows. Many birds, reptiles and amphibians were also spared; saved by their small body size and flexible, often insect-based, diets. Some freshwater species also fared well; their food chain includes detritus – nutrients released by decomposition – which washes into streams and lakes, providing a steady supply of fuel.

As Earth started to recover there were gaps in the food chain for these animals to fill and the survivors spread out to take the places of the dinosaurs. Over time they evolved to become the huge variety of species that we see today.

Small animals including mammals survived the KT extinction

ADVERTORIAL

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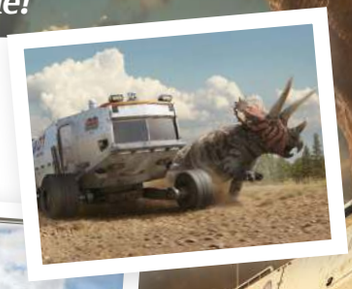

When do scientists think the last of the dinosaurs may have gone extinct?

A 65 years ago
B 65 thousand years ago
C 65 million years ago

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Hadrian's Wall

The epic barrier that became a symbol of Roman power and authority in Britain

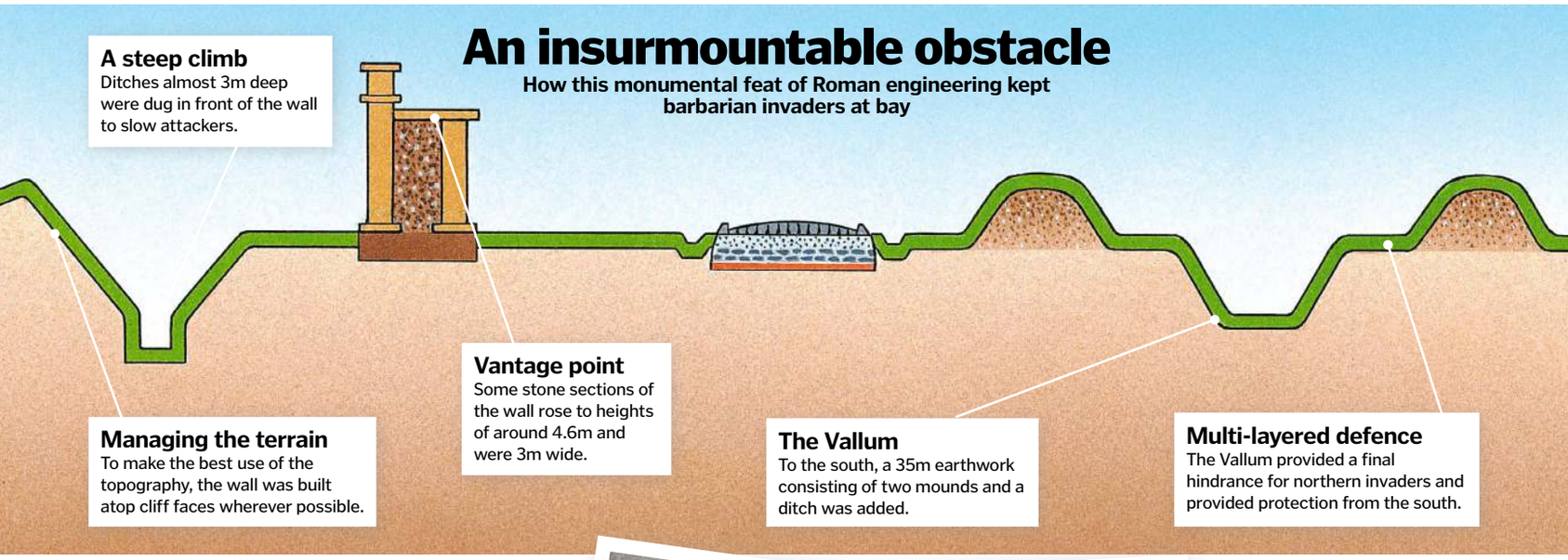
When Emperor Hadrian ascended to power in 117 CE he inherited an empire at the height of its reach, one that stretched from northern Africa to northern England. The new emperor was concerned that Rome would have difficulty holding its borders, and so he commanded his legions to construct a great wall in northern England to protect against the peoples of the Scottish lowlands.

The wall was built mostly from stone and the remainder in turf, stretching for approximately 120 kilometres from coast to coast. It was reinforced by guard posts, sentry towers, forts and ditches, which were erected alongside its impregnable face. It took over 15,000 soldiers less than a decade to complete, and for centuries after it stood as both a practical defence and a symbol of Roman might.

The foundations of Hadrian's Wall still stand today

An insurmountable obstacle

How this monumental feat of Roman engineering kept barbarian invaders at bay



A steep climb
Ditches almost 3m deep were dug in front of the wall to slow attackers.

Managing the terrain
To make the best use of the topography, the wall was built atop cliff faces wherever possible.

Vantage point
Some stone sections of the wall rose to heights of around 4.6m and were 3m wide.

The Vallum
To the south, a 35m earthwork consisting of two mounds and a ditch was added.

Multi-layered defence
The Vallum provided a final hindrance for northern invaders and provided protection from the south.

Geoglyphs

The works of art that use expanses of earth as their canvas

Across multiple continents including North America, South America and Europe lay pieces of land that look rather unspectacular as you stand upon them; but if you were to change your viewpoint to a nearby hilltop, they would be revealed as intricate and spectacular shapes. These are known as geoglyphs: large geometric patterns carved into the ground using earth and stone.

The patterns depicted by geoglyphs vary considerably, but researchers have been able to identify two main construction methods. The first involved scraping away the top layer of soil to expose the coloured rock underneath; the second was almost the opposite, as material was piled upon the soil to create the design. There are also examples of particularly laborious builds such as the Uffington White Horse in the UK, which was built from a curved ditch packed full of chalk.

The purpose of the various geoglyphs found around the world is still somewhat of a mystery to scholars. Some are believed to be symbols of status, another as a navigational tool for sailors, and others as a representation of the constellations in the night sky. But although the knowledge of their function is lost, they continue to act as beautiful reminders of the resourcefulness and capabilities of different ancient cultures.

Geoglyphs look spectacular from afar, but why they were made remains a mystery

Heraldry

The colourful graphic emblems that identified medieval knights and are displayed by their descendants today

The image of a knight holding a shield bearing his coat of arms as he attempts to strike a blow to his opponent is a familiar one in the movies. In these medieval tournaments, when the combatants wore full armour, these colourful emblems were the only way they could be identified. Much the same applied in warfare; the Bayeux Tapestry, which depicts the famous 1066 Battle of Hastings, appears to show a precursor of 'modern' heraldry on the battlefield.

Heraldry came about in an era when most people couldn't read or write. So instead of words, simple bold symbols were used to show the identity of the bearer. However, an essential requirement in heraldry is that no two individuals share the same coat of arms. This requirement soon resulted in ever more complicated designs and, eventually, this led to the appointment of heraldic authorities to formalise the process. The job of the herald was to grant arms to individuals and to keep records, a task that continues today by Crown appointed officers of arms in the College of Arms.

As part of the regulation of heraldry, a formal way of describing a coat of arms was devised. Called a blazon, this description is unique and unambiguous and provides sufficient information for a heraldic artist to reproduce the coat of arms. It can be something of a mystery to the uninitiated, though, as the following example illustrates.

The blazon for the coat or arms shown on page 25 is "Quarterly: 1st and 4th, Argent three Lozenges conjoined in fess Gules within a Bordure Sable (Montagu); 2nd and 3rd, Or an Eagle displayed Vert beaked and membered Gules (Monthermer)". The strange turn of phrase results from the fact that not only is there a very precise way of describing things but also because the vocabulary is a mixture of English, Norman French and Latin. Some of the words – for example Eagle and Bordure – are either English or French words that are easily recognisable, and some are heraldic words that really don't have everyday uses, such as 'lozenge', which is a diamond shape, or 'chevron', an inverted v-shape.

The so-called 'tinctures' are puzzling, though. These are divided into colours: azure (blue), gules (red), sable (black), vert (green); metals – argent (silver) and or (gold); and furs – ermine, ermines, erminois, vair, vair ancient and counter-vair. It's also interesting that there are specific rules about how tinctures can be used. According to the rule of tincture, a coat of arms cannot have a colour on another colour or a metal on a metal so, for example, the coat of arms described as "Argent a chevron Or" (silver on a gold chevron) would not be allowed.

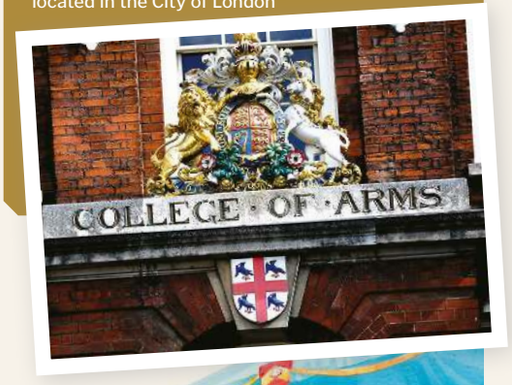
Heraldry might have its roots in the mists of time but, if you want to get to grips with this ancient form of art, there's plenty of software to lend a hand. An interesting online resource can be found at **drawshield.net**. Here there's a tool for creating coats of arms and there's even a facility that attempts to draw one from a blazon.

"The Bayeux Tapestry appears to show a precursor of 'modern' heraldry on the battlefield"

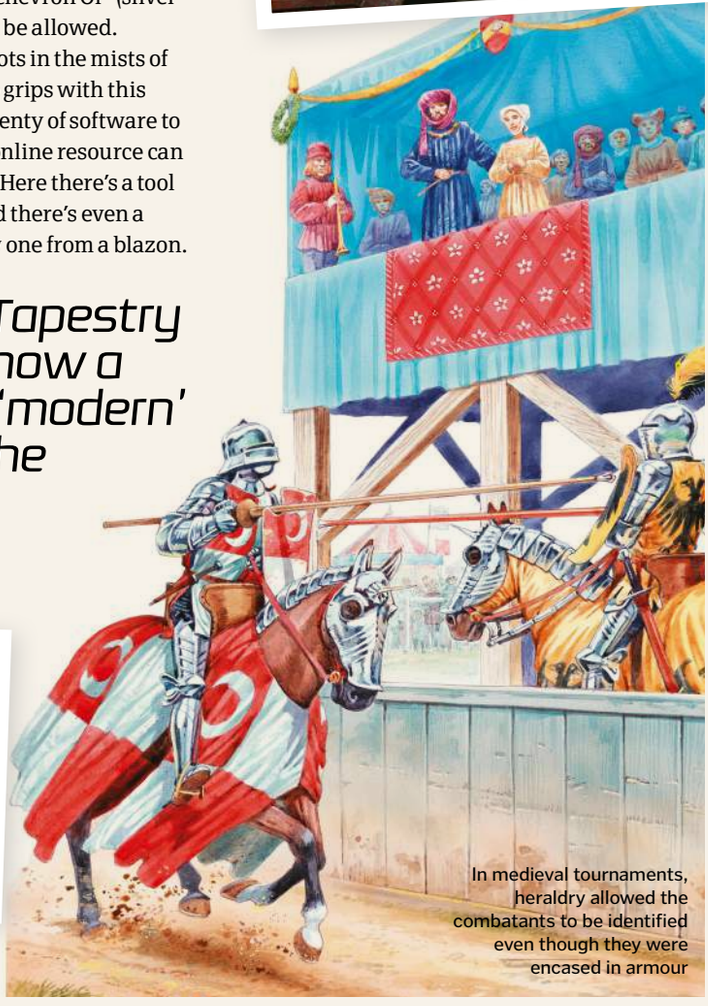
The College of Arms

Re-established by royal charter in 1555 and occupying a building that dates back to the 1670s, the College of Arms is the official heraldic authority for England, Wales, Northern Ireland and much of the Commonwealth. As well as maintaining detailed registers of arms, pedigrees and genealogies, the College is also responsible for the granting of new coats of arms to qualified bearers.

The College of Arms is comprised of 13 officers of arms, the most senior of which are the Kings of Arms. Under the authority of the Crown, the Kings of Arms have the power to grant new coats of arms to both individuals and corporate bodies.



The College of Arms' headquarters is located in the City of London



In medieval tournaments, heraldry allowed the combatants to be identified even though they were encased in armour

The right to bear arms

It's commonly thought that people are entitled to bear a coat of arms that's associated with their family name. Lots of companies offer products featuring your 'family coat of arms', but this is just playing in to the common misconception that arms are connected to surnames. People with the same name might be entitled to completely different arms, while others of that name will be entitled to no coat of arms at all. Instead, coats of arms were granted to individuals – as they still are today – and are passed on through the male line of descent. It's possible that you might be entitled to bear arms, but to be sure you'd need to carry out some detective work in tracing your ancestry.

There's no such thing as a family coat of arms

The heraldic achievement

The heraldic components to which a bearer of arms is entitled to display

Crest
Originally a decorative sculpture worn by knights in tournaments, the crest is the top-most part of the heraldic achievement and often takes the form of an animal.

Torse
The torse is a twisted strand of six folds, possibly originating as a lady's favour. It alternates the two principal tinctures in the arms.

Helmet / Helm
With obvious military connotations, the helmet or helm can be of several styles that denote the rank and social status of the bearer.

Mantling
A small cloak in the main colours of the arms, the mantling is displayed behind the helmet.

Crown / Coronet
If the bearer is a baron or above, he is entitled to display a crown or coronet above the shield. The design of the crown indicates the rank.

Supporters
The supporters, which can be human, animal or mythical, stand either side of the shield. They are usually limited to hereditary peers and the royal family.

Shield
The shield is the most important part of the heraldic achievement and can also be used on its own. Various slightly different shapes can be used.

Divisions
Often the shield is divided into several parts. This shield is quartered, but they can also be split into two parts in several different ways. Divisions can be sub-divided.

Charges
Usually, the shield or its divisions contain charges. Animals, sometimes mythical, are common and poses differ. A lion, for example, can be rampant or passant.

Motto
Often in Latin – other languages can be used – the motto appears at the bottom of the heraldic achievement.

Ordinaries / Sub-ordinaries
Some charges, like the lozenges and bordures here, are simple geometric shapes. These are referred to as ordinaries or sub-ordinaries.

Containing 719 separate coats of arms, the Stowe armorial is an extreme example of quartering

HI-TECH HAPTICS

How haptic technology is going beyond sight and sound to get us hands-on with the virtual world

What if you could explore far-flung countries and reach out to touch the animals and plants all around you with your fingertips? Or feel the rumbles of being aboard your own spaceship as you pilot it through an asteroid belt by yourself? How would it feel to score the winning goal in the biggest football game of the century and actually feel what it'd be like to kick the ball into the net? Welcome to the world of haptic technology.

Haptic comes from the Greek word *haptesthai*, which means 'to touch' and is used to describe anything that relates to our sense of touch, just like the word optic is linked to our sense of sight. So, as you'd expect, haptic technology is all about creating experiences and interfaces that you can interact with using touch.

Once you've touched them, tapped them or held them, these interfaces then deliver a physical feeling back to you, which is often called haptic feedback or force feedback. This haptic feedback can feel like all kinds of things, from a vibration when you bump into something in a virtual reality game to being able to pick up a syringe and feel a resistance against a person's skin if you're training to be a doctor. Essentially, haptic technology is about making something that is not real feel real.

Up until now, being able to feel forces when you're playing a game or taking part in a virtual

Types of touch

Many of us would consider touch as a single sense, but researchers believe it should be considered multisensory. That's because there are two submodalities at play that make up our sense of touch: cutaneous and kinesthetic. The cutaneous system is all about what the skin feels. This is sensed by mechanoreceptors embedded in the skin that can detect pressure, temperature and pain.

The kinesthetic system is all about how the body is positioned and what's going on inside it. This is sensed by mechanoreceptors in the muscles, tendons and joints that are able to sense positioning and feelings of motion.

The haptic system is a combination of inputs from both the kinesthetic and cutaneous systems. It's also considered an active rather than a passive form of touch. These definitions vary, but most researchers agree active touch is when someone is using motor commands to control their muscles and respond to touch rather than passively being touched by something or someone else.

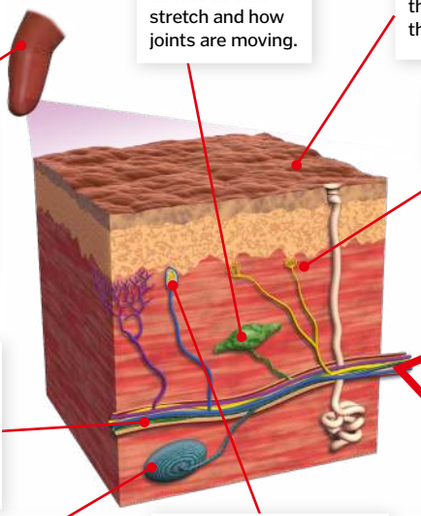
There's far more to our sense of touch than meets the eye

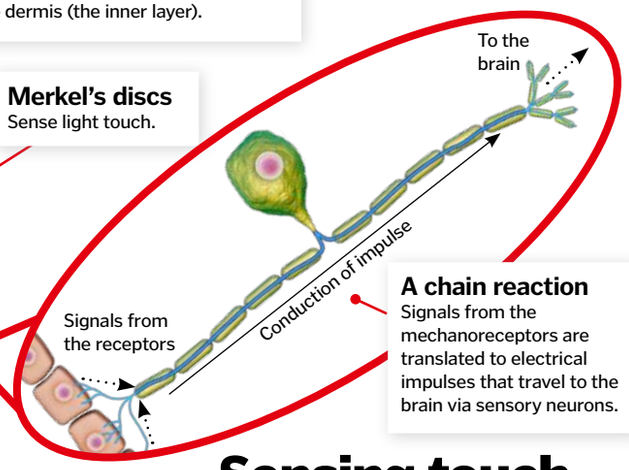
Ruffini endings
Detect warmth, as well as skin stretch and how joints are moving.

Different layers
The skin consists of two major layers: the epidermis (the outer layer) and the dermis (the inner layer).

Skin senses
The skin is the largest sense organ in the body, and in the average adult it can cover an area of two square metres.

Merkel's discs
Sense light touch.





A chain reaction
Signals from the mechanoreceptors are translated to electrical impulses that travel to the brain via sensory neurons.

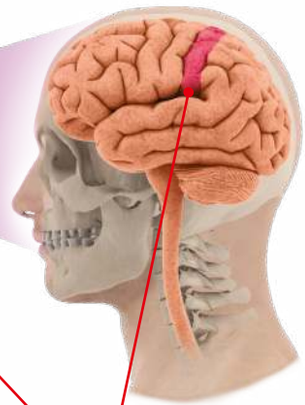
Sensory neurons
Mechanoreceptors are found in the skin. Sensory neurons, they can detect touch, motion and monitor your body's position.

Pacinian corpuscles
Sense deep pressure and high-frequency vibration.

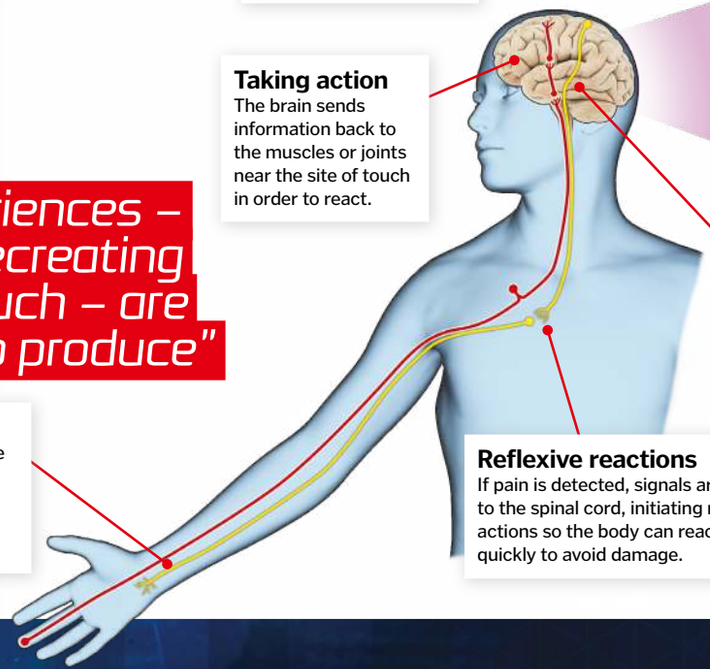
Meissner's corpuscles
Respond to fine touch and pressure, as well as low-frequency vibration.

Sensing touch

How the body touches, feels and reacts to the world



Taking action
The brain sends information back to the muscles or joints near the site of touch in order to react.



"Haptic experiences – focused on recreating a sense of touch – are much harder to produce"

Neural pathways
Sensory signals travel from the body to the brain via sensory neurons (red). The brain can initiate movement in response via motor neurons (yellow).

Reflexive reactions
If pain is detected, signals are sent to the spinal cord, initiating reflex actions so the body can react quickly to avoid damage.

Brain processing
Sensory information enters the thalamus, which relays the sensory information to the sensory cortex to be processed and understood.

reality experience has been confined to theme parks and arcade games, like flight simulators or motion platforms. But that doesn't mean you won't have experienced force feedback on a smaller scale before. Examples include the home button on the latest iPhone, which vibrates when you press your finger on it, the rumble features on many games controllers, and even the small vibrations your fitness tracker sends you when you hit your daily steps goal. These are examples of haptic technology in action in your day-to-day life; they recreate a force when you either reach a goal or interact with your gadgets in some way.

Now, thanks to advances in technology, this kind of force feedback will not just be available at a high price at theme parks or in the form of tiny vibrations in your pocket. Instead, it's already proving to be useful, work intuitively and has started making waves in all areas of our lives, from entertainment in our living rooms to training in our hospitals.

Most experiences we have with technology are visual and aural, like watching a movie, playing with an app, or experiencing virtual reality with a headset and a pair of headphones. But haptic experiences – focused on recreating a sense of touch, like a force, vibration or temperature – are much harder to produce.

The first thing to consider is that haptic systems are bidirectional. This means you don't just sense what's going on, but when you touch something, you affect it too. In contrast, when you watch or hear something you have no effect on it. That means it's easier and cheaper to recreate visual and aural displays and experiences. You don't need to think about the effect others will have on what you've created, and they can also be experienced from a distance.

But more and more industries and tech companies are realising that adding haptic feedback to everything from training simulations to games is really important. That's because we see and hear lots of things that aren't real, like a movie about dinosaurs or a musical track that sounds like waves. Often it's not hard to suspend our disbelief and imagine we're actually among the Pterodactyls or sat by the sea. But it's harder to fool your sense of touch and immerse yourself in a virtual world by feeling it. That's why it's been difficult for tech companies to create realistic haptic experiences without advanced and expensive technology. It's also why creating realistic haptic experiences could open up the most possibilities, because if you get it right, it's the most convincing sense.

How can haptic tech help?

How a sense of touch could save lives and enhance technology

Training medical professionals

Operations, injections and complicated procedures can be rehearsed in virtual environments, giving trainees more hands-on practice than ever before.

More immersive gaming

Gaming companies have long been working on haptic gloves and bodysuits to make in-game experiences, like fighting, falling and flying, feel more realistic than ever, all over your body.

Keeping soldiers safe

The military has been experimenting with haptic technology for years. One simple application is using vibrations to help soldiers navigate their way through new environments when audio guidance is too risky.

Controlling robots and machinery

Teleoperation involves controlling robots or hardware remotely. It works without haptic tech, but touch makes operating machinery in space, under the sea and in medical procedures safer and more effective.

Touching virtual worlds

Using motion sensors and full body exoskeletons, haptic tech can add a higher level of immersion and presence to virtual experiences, from entertainment and interaction to therapy and pain relief.

For example, some researchers believe that our bodies read touch information 20-times faster than sight information. So if you're operating machinery via a screen and you're only seeing what's going on, you're missing out. If you could feel it, too, your reactions would be quicker. The same applies to gaming, skills training or any other kinds of problem-solving.

On top of that, touch is also believed to be one of the most effective channels for social communication. So if companies are keen on developing social interaction tools with VR tech, such as Facebook, then adding in touch will make them more effective.

Meet the bionic fingertip

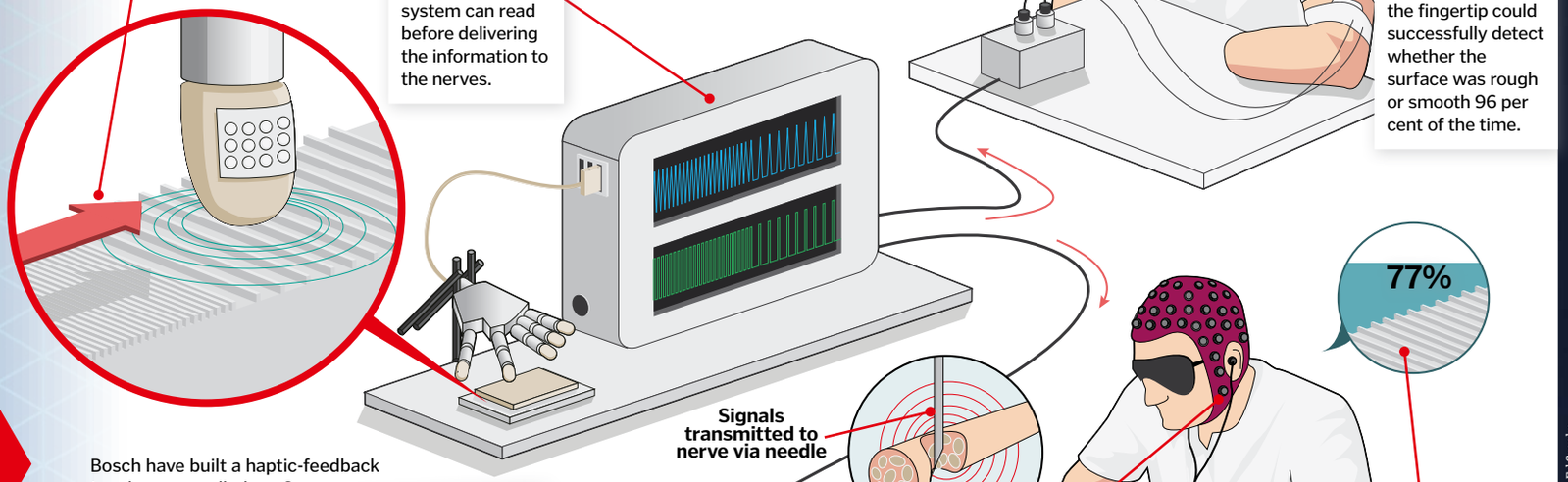
How researchers are using an artificial finger to enable amputees to feel touch again

"Haptic experiences open up many possibilities – if you get it right, it's the most convincing sense"

Packed with sensors
The fingertip moves across a textured surface and sensors generate different electrical signals depending on how smooth or rough it is.

Translating the signal
These signals are turned into electrical spikes, which the nervous system can read before delivering the information to the nerves.

Sensor implants
The artificial fingertip's sensor was connected to nerves in the amputees' upper arms. In non-amputees the fingertip signals were transmitted to nerves via needles.



Amputees can feel again
Amputees using the fingertip could successfully detect whether the surface was rough or smooth 96 per cent of the time.

Convincing the brain
Using an EEG test, researchers found the brain couldn't tell the difference between a real fingertip or the artificial one.

Testing with non-amputees
Non-amputees who used the bionic fingertip could tell 77 per cent of the time whether the surface was rough or smooth.

Bosch have built a haptic-feedback touchscreen called neoSense

Feeling with prosthetics

Prosthetics now look and behave more like real limbs than ever before. Recreating a sense of touch for amputees is important because it allows them to fully interact with the world. Studies also show that touch feedback is vital in helping people see their prosthesis as not just a tool but a body part.

Scientists have conducted research into the different ways artificial hands can produce real feelings of touch in the brain. One way is through a haptic feedback device that applies pressure to someone's upper arm to varying degrees as they grasp things with their hand.

Another method is to place sensors within an artificial hand that relay texture, pressure and friction information to electrodes that are surgically implanted around nerve bundles in a person's upper arm before being transmitted to the brain, which interprets them as the same feelings as a normal hand.

Incorporating a sense of touch in prosthetics and bionics can enable amputees to perform activities more easily

There are many different ways to create haptic displays, but most contain two key parts: sensors and actuators. Sensors are the bits of the tech that can sense the haptic information that's being exerted by someone, like you pushing a door with your hand in a VR game while wearing a special haptic glove. They read this information and send the force readings to the haptic rendering module.

The actuator then reads this haptic data and transforms it into a form that we can perceive, as force or vibration, like feeling resistance in the glove because the door in the game is heavy and hard to open. But whatever that form is, it can then be delivered in a number of ways. Some of the most common ways that we're all used to are vibrations through screens and buttons. But in gaming you can also feel forces through a stylus, joystick or glove. Because touch can be felt all over the body there's a huge opportunity here for tech companies to create more innovative methods of delivery.

One example is the haptic bodysuit. For decades now companies have been working on ways to create an all-over force feedback experience, which will make VR and gaming feel a lot more real. Imagine feeling sensations on your back and shoulders as you surf waves rather than just a vibration in your hand, or feeling a jab to the leg when you're using a VR headset for martial arts training and someone has just delivered a great roundhouse kick.

A number of commercial companies have created suits over the years, such as Teslasuit, which can provide force feedback to 46 haptic points all over your body. AxonVR, another tech company, has combined a similar suit with a robotic arm to create the HaptX Skeleton.

Thanks to tech becoming more advanced and smaller, as well as the mainstream adoption of VR headsets, these suits and exoskeletons have now reached the stage where they can be snapped up by regular consumers. In the future we expect these kinds of all-over body experiences to become commonplace and suits to become more effective, advanced and hopefully affordable.

Looking further into the future, you may not always need a physical controller or even a suit to feel touch sensations. Disney has been exploring ways to recreate a sense of touch that doesn't require any hardware and can be felt with just your hands. The company's AIREAL device uses air vortex rings to create shapes and objects that you can feel in the air, which would be really useful for virtual reality worlds, as well as theme park rides and entertainment.

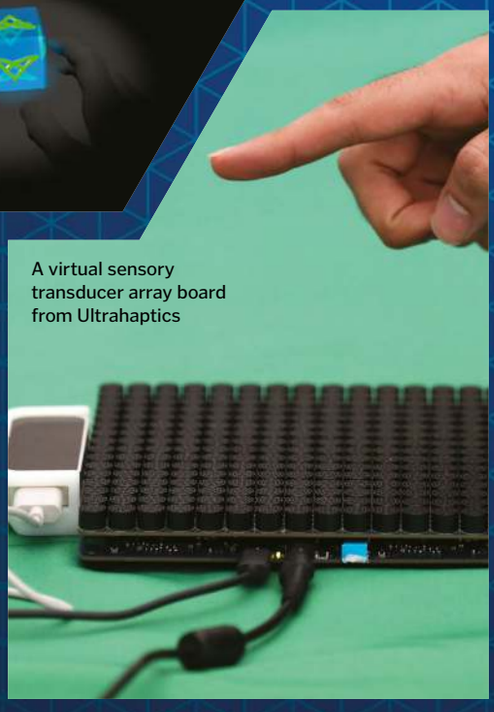
Similarly, a company called Ultrahaptics is using ultrasound technology to project sensations directly onto your hand from an

"By combining VR and haptic tech, people can learn new skills in a safe environment"

Experiencing haptic VR surgery with VirTeaSy Surgery in France

In a VR environment, haptic tech can make it feel like you're really holding virtual objects

An attendee at the VR World Congress tests a haptic technology dental training device from Generic Robotics



A virtual sensory transducer array board from Ultrahaptics

Haptic tech in space

Haptic technology is proving to be very useful when it comes to remote training, learning and interaction, so it's hardly surprising that NASA has been exploring the role it could play in future space missions.

Haptics-2 is a haptic tech experiment that was set up aboard the International Space Station (ISS) to test how well touch feedback can work when it's being controlled from orbit and felt on the ground, as well as vice-versa. Astronauts trialled the tech on the ISS to learn just how smooth and useful it could be from such a great distance.

NASA believes haptic tech could be useful for future missions. For example, space crew could better control robotic assets from orbit that are located on Mars, distant asteroids or any other kind of place we might want to find out more about, collect samples from or just explore but aren't capable of touching down on ourselves yet.

Astronaut Thomas Pesquet works with controls for the Haptics-2 experiment aboard the International Space Station

interface without anything in between. Although this kind of technology is still very new, eradicating the need for any extra hardware is bound to be more appealing to regular tech lovers and big businesses in the long-run. The challenge now is to package this technology in a way that people can actually use outside of a research lab.

Although it's easy to see how haptic feedback can be used to make mainstream virtual reality headsets feel even more immersive and to add extra realism to gaming, there are many other ways haptic technology is making a difference.

When doctors, dentists and any other kind of medical professional are training, they need to perform procedures from standard injections through to complicated surgeries. By combining visual screens or VR headsets with haptic feedback, people can train in an environment that's safe and gives them plenty of room to learn and make mistakes.

For example, UK-based Generic Robotics has been working on SimuTeach. The result is a combination of VR, robotics and haptic technology that creates an intra-oral injection simulator, which allows trainee dentists to practise giving an injection in an environment of unparalleled safety.

And that's just the beginning. Although haptic feedback seems so appealing because it allows us to touch virtual worlds, it can also be used to let us better interact with the real world, too. One great example is the way force feedback is becoming invaluable for telerobotics. This type of feedback is particularly helpful when someone is controlling a robot or machine from a distance. With the help of haptic technology, controlling a remote robot becomes not only easier but much more efficient. As these kinds of robots are used in dangerous situations, such as nuclear power plants, anything that will improve telerobotic operations has the potential to revolutionise countless industries.

A medical student using a 3D display and a haptic device to train for eye surgery procedures

On a more personal scale, haptic technology could be added to many of our favourite gadgets. Right now we know many electronics vibrate, but these small force feedback cues could be used more and more, like when you move a folder to a new spot on your desktop. Perhaps in future you'll be able to programme different forces, textures and even temperatures depending on the kinds of notifications that you wish to receive.

As haptic technology advances it will no longer be confined to research labs or theme parks. Instead, experiences that go beyond sight and sound will be coming to homes and businesses across the world, making gaming feel more sensational and helping robots to get better at their jobs. With this technology still in its infancy, we can be sure that an exciting futures lies ahead.

History of haptics

The evolution of touch-based tech

1829 Louis Braille first publishes his tactile writing system, changing the way blind and visually impaired people write and read.

1965 E A Johnson invents the first finger-driven touchscreen, which would later be known as capacitive touch.

1989 The UK's Advanced Robotics Research Centre unveils the Teletact Glove, which recreates a touch sensation through tiny airbags.

1993 IBM and BellSouth join forces to launch the Simon Personal Communicator, one of the first phones with touchscreen technology.

1994 Aura Systems launches the Interactor Vest, a gaming wearable that converts sound waves into vibrations that represent actions, like a punch or explosion.

1997 Nintendo launches the Rumble Pak, an attachment for the Nintendo 64 controller that uses vibrations to provide force feedback during game-play.

2013 Disney introduces its AIREAL haptic tech research, which uses air vortex rings to simulate touch without a glove or physical tool.

2015 Apple introduces its haptic user interface to the iPhone, MacBook and Apple Watch and calls it the Taptic Engine.

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Location: **The Victoria and Albert Museum, London**
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Supported by the American Friends of the V&A
Dates: **15 July – 12 November 2017**
Price: **Admission-free**

Plywood: Material of the Modern World

Discover the versatility of an often overlooked material in a new exhibition at the V&A

Light, strong, affordable and versatile, plywood is the unlikely material behind an eclectic array of groundbreaking designs to be celebrated in a world-first exhibition at The V&A this summer. From the fastest and highest-flying aeroplane of WWII, the de Havilland Mosquito, to the downloadable self-assembly WikiHouse, more than 120 objects are brought together in an exploration of how plywood helped create the modern world.

Fragments of layered board have been found in ancient Egyptian tombs, but it was the advent of mass production in the 19th century that saw plywood's adaptability and potential fully exploited. Used to construct everything from an experimental elevated railway in 1867 New York to hatboxes, tea chests, surfboards and skateboards, plywood has been embraced by designers, architects and engineers, each successive generation finding ever more innovative ways to work with it.

Plywood explores this near-ubiquitous material's global impact and history from the 1850s to the present day. The exhibition brings together significant new research with new acquisitions and objects that have never before been on public display. It takes visitors through plywood's many reputational transformations; from a cheap product that was maligned for its inferiority to solid timber, to the material prized by mid-century modernists and by today's flourishing maker movement.

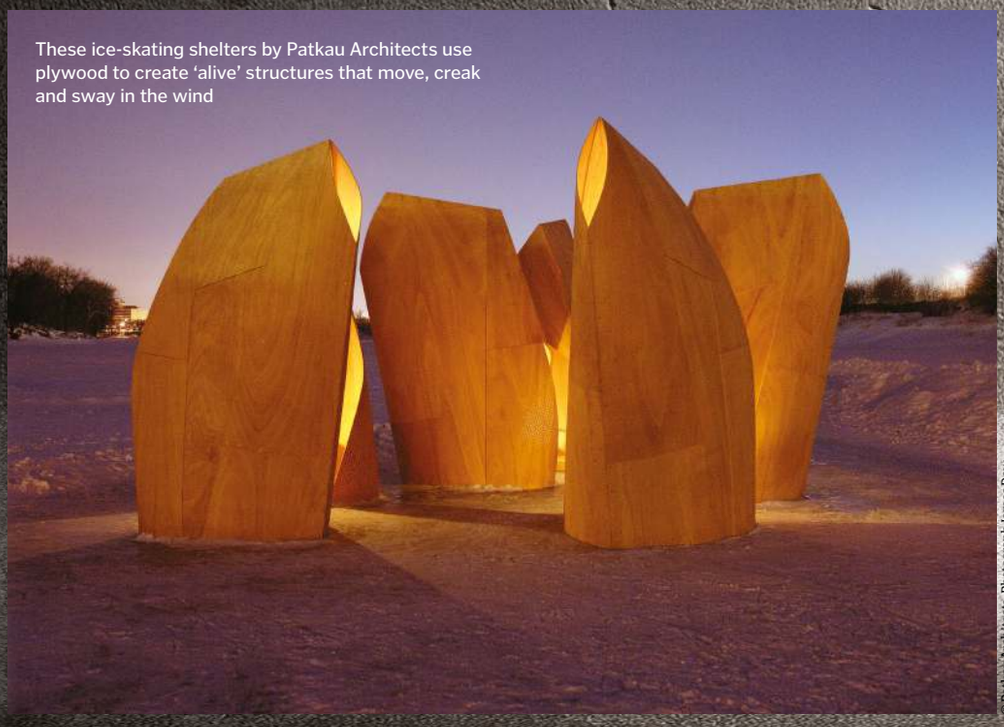
Coupling objects drawn from The V&A's world-class furniture, design and architecture collections with significant loans from across the globe, highlights include early experiments in plywood, such as a 1908 book printed during Ernest Shackleton's Nimrod expedition to Antarctica and bound with plywood covers; celebrated pieces by modernist designers such as Alvar Aalto, Marcel Breuer, Grete Jalk, Robin Day and Charles and Ray Eames; and striking examples of transport design, such as a 1917 moulded canoe, a 1960s British racing car with plywood chassis, and some of the first ever surf and skate boards.

Interspersed throughout the displays are three 'process' moments that mark important milestones in the evolution of plywood manufacture: the invention of the rotary veneer cutter in the early 19th century; the advent of moulding techniques that inspired the groundbreaking forms of 1930s modernism; and plywood's recent dominance as a material for CNC-cutting and digital manufacture.

The V&A houses over 2.3 million objects spanning over 5,000 years of human creativity

© James Medcraft, Victoria and Albert Museum

These ice-skating shelters by Patkau Architects use plywood to create 'alive' structures that move, creak and sway in the wind



© Patkau Architects, Photograph James Dow

© de Havilland Aircraft Museum

The de Havilland Mosquito, used by the RAF during WWII, was made almost entirely of plywood, earning it the nickname 'The Wooden Wonder'

© Alvar Aalto Museum, Photograph Victoria and Albert Museum, London

The sitting position of the Paimio Chair was designed to enable tuberculosis sufferers to breathe more easily

The use of plywood in the Eames DCM chair inspired the design of hundreds of plywood chairs all over the world

© Eames Office, LLC, Photograph Victoria and Albert Museum, London

At the Madison Home Show in 1937, a full-scale house was built from plywood to demonstrate a prefabrication system designed by the US Forest Products Laboratory

© USDA Forest Products Lab

"Plywood has been used to construct everything from hatboxes to tea chests and surfboards"

Agas

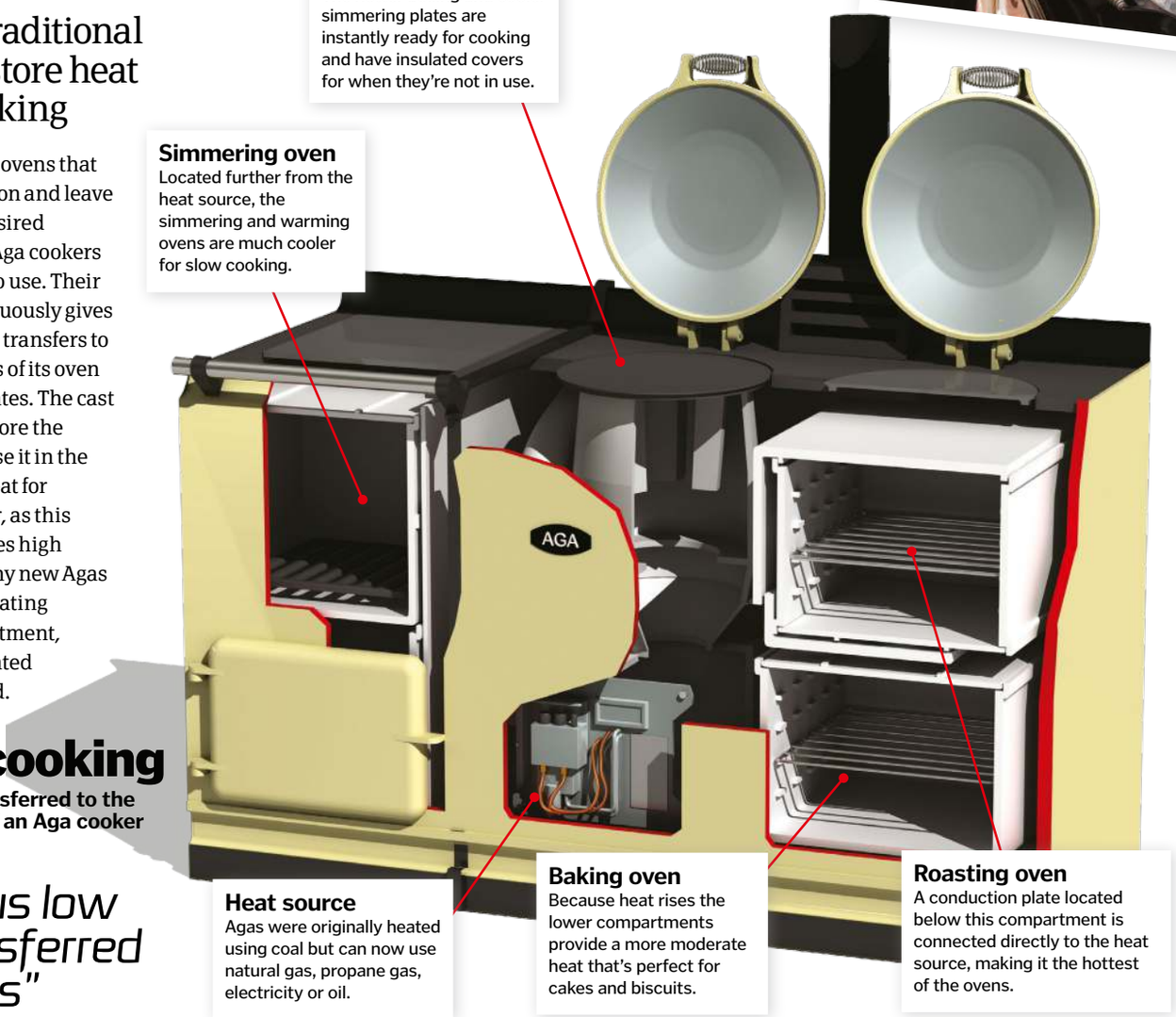
Discover how traditional range cookers store heat for efficient cooking

Unlike conventional ovens that you have to switch on and leave to heat up to the desired temperature, traditional Aga cookers are always on and ready to use. Their central heat source continuously gives off a low heat that steadily transfers to all of the cast iron surfaces of its oven compartments and hotplates. The cast iron is able to efficiently store the thermal energy and release it in the form of a gentle radiant heat for all-over cooking. However, as this method of cooking requires high energy consumption, many new Agas now feature individual heating elements for each compartment, enabling them to be operated individually when needed.

Agas not only cook your food but give off enough heat to warm your kitchen too

Cast iron cooking

Explore how heat is transferred to the clever compartments of an Aga cooker



Hotplates
The hotter boiling and cooler simmering plates are instantly ready for cooking and have insulated covers for when they're not in use.

Simmering oven
Located further from the heat source, the simmering and warming ovens are much cooler for slow cooking.

Heat source
Agas were originally heated using coal but can now use natural gas, propane gas, electricity or oil.

Baking oven
Because heat rises the lower compartments provide a more moderate heat that's perfect for cakes and biscuits.

Roasting oven
A conduction plate located below this compartment is connected directly to the heat source, making it the hottest of the ovens.

"A continuous low heat is transferred to the ovens"

Digital kitchen scales

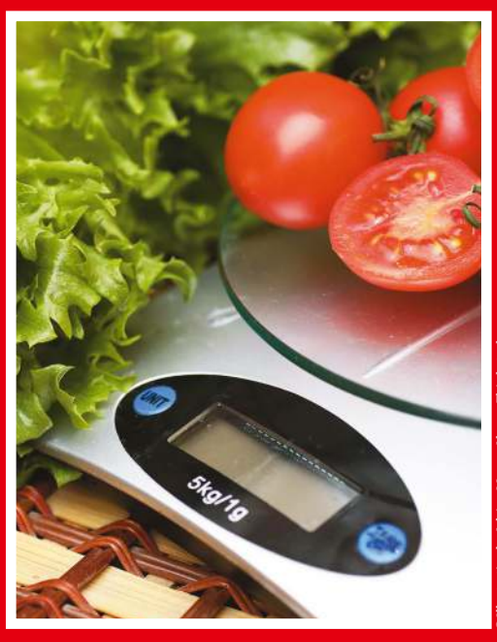
The mechanics that help you weigh your recipe ingredients precisely

Whether you use a spring scale with an analogue dial or a digital scale with an LCD screen, your ingredients are being weighed mechanically. The main difference between them is how measurements are displayed, with the latter converting the analogue reading into digital information.

When you place an object onto a modern scale its weight applies force onto a load cell and causes it to bend. A load cell is a type of transducer that converts one form of energy into another, and in household digital scales a strain gauge load cell is typically used.

The strain gauge is a circuit board with metal tracks or foil bonded to it, and when it bends under pressure its electrical resistance changes. This is measured using a type of electrical circuit called a Wheatstone bridge, which balances the resistance of the strain gauge against resistances elsewhere in the circuit, similar to how traditional balance scales measure weight.

The resistance change measurement is then transmitted as an electrical signal to the scales' central processing unit (CPU), which then converts it into the numbers you see on the display screen.



Fishing rods

How rods, reels, lines and lures help us catch fish

Fishing is an ancient practice at least 40,000 years old, with archaeological finds including hooks made from bone dated as far back as the Stone Age. Traditionally, fishing rods have been made from bamboo, but today most are built from carbon fibre or fibreglass.

A fishing rod's main function relies on energy transfer through the rod and bending to deliver power. The potential energy stored in a rod must be transferred all the way to the end of the line. This is done by casting a smooth stroke, building in acceleration, until it is abruptly stopped to allow the rod to return to a straight position while the energy is transferred to the line, causing the line to launch towards its target.

There are two main types of fishing that each rely on their own set of expertise to be executed successfully. Spinning rod fishing uses bait, such as worms or insects, or artificial bait 'lure' made to resemble a small prey fish. These rods are designed so the weight of the bait pulls out the line and causes a splash as it lands. Between 80-150 precision-built components of the reel allow an angler to cast long distances, while stainless steel ball bearings allow it to spin more than 10,000 revolutions per minute.

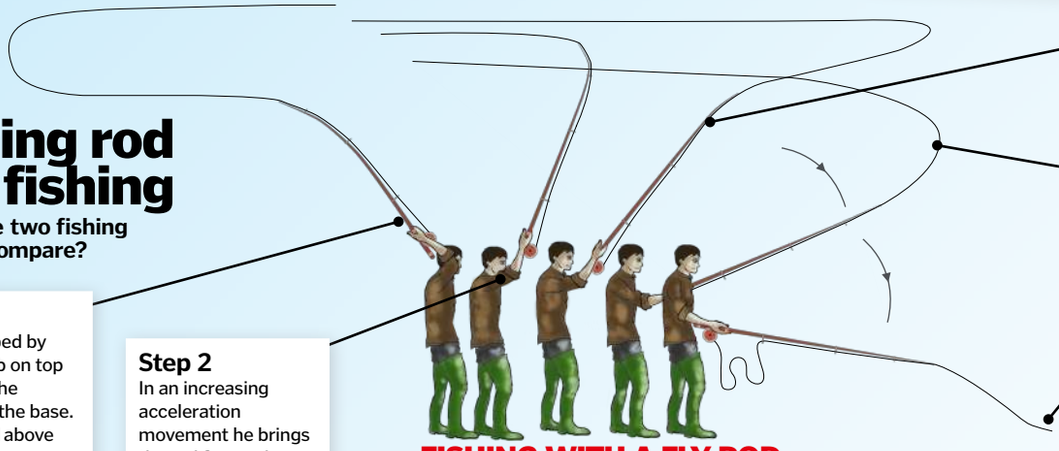
Fly fishing relies on tiny lures called 'flies' that are made to resemble insects and are light enough to avoid startling fish with a splash. They rely on the weight of the line to launch the almost weightless fly. These are attached to an almost invisible thin line up to around 4.5 metres long called a leader, which is attached to a thicker, braided line that's even longer and weighs a lot more. The trick to fly fishing is to allow the thicker line to hit the water first so that the fly lands further along with no splash.

In fly fishing, the reel is only used to store the line and is released by hand before being cast. But in the spinning rod, the line is held down and released at the right moment to fling the bait or heavy lure into the water.

Rods must be strong in order to reel in a large catch without snapping under the strain

Spinning rod vs fly fishing

How do these two fishing techniques compare?



Step 1
The rod is gripped by placing a thumb on top and wrapping the fingers around the base. It is then raised above the shoulders.

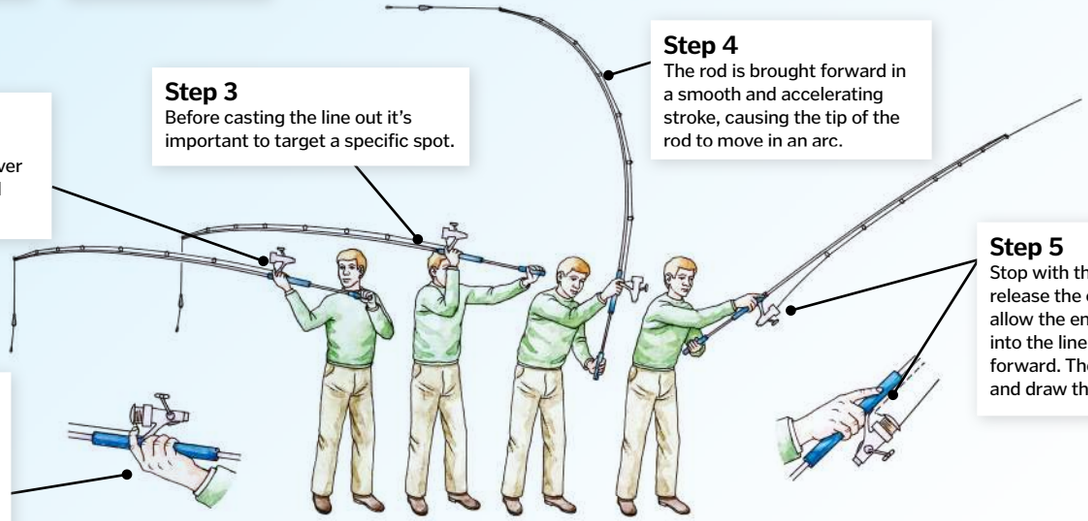
Step 2
In an increasing acceleration movement he brings the rod forwards.

Step 3
When his arm is at an angle of around 45 degrees he stops the rod abruptly.

Step 4
Energy is transferred through the rod and into the line.

Step 5
Energy is then transferred from the thicker line to thinner leader and fly, which lands delicately in the water.

FISHING WITH A FLY ROD



Step 1
The button on the side of the casting reel is held down to prevent the line unravelling before it's cast.

Step 2
The rod is brought backwards and held over the shoulder while still holding the button.

Step 3
Before casting the line out it's important to target a specific spot.

Step 4
The rod is brought forward in a smooth and accelerating stroke, causing the tip of the rod to move in an arc.

Step 5
Stop with the rod tip high and release the casting reel to allow the energy to transfer into the line and send it forward. The bait will continue and draw the line out.

FISHING WITH A SPINNING REEL

Cozmo

How It Works meets the little robot with a big brain and bigger personality

There's a popular saying that states how big things come in small packages, and that couldn't be more true for Anki's new robot, Cozmo. The little robot looks as if it's come straight out of a Hollywood movie, and it has the brains and the personality to reinforce that idea. Before its launch in the UK in September this year, **How It Works** was invited to meet Cozmo and have a play with the droid confidently dubbed a 'supercomputer on treads'.

As soon as you wake Cozmo from his charging pad – via the interactive app downloaded onto a smartphone or tablet – his animatronics come into play. He greets the party with a sleepy yawn and casually rolls off the pad, lifting his arms and making curious noises. Cozmo has been meticulously programmed with flexible behaviours that are activated at various times, and so before prompting you to play a game via the companion app, he may choose to wander and explore. At this point his advanced sensor equipment maps the terrain in front of him and his small, manoeuvrable body easily navigates the flat surface.

After roaming for a while he stops, raises his head and pivots on the spot, searching for a familiar face. Cozmo's cameras can swiftly identify human features (as well as those of cats and dogs), and after being instructed to commit a new face to memory he will recognise that person in future.

Although Cozmo's personality is apparent as soon he wakes, it doesn't truly come to the fore until you bring out his Interactive Power Cubes. You can play multiple games against Cozmo this way and watch as he either celebrates a victory with a squeak and a twirl with his arms raised or throws a tantrum after a defeat. Alternatively, you can let him play with the cubes himself and admire his advanced processing power as he aligns himself with his stack of assembled cubes and laugh as he knocks them over in an act of mischief shortly after.

Before long Cozmo had been sent back to his charge pad and was snoring loudly. As we had yet to see his violent sneezing, acrobatic flips, and a huge number of other things, we couldn't wait to wake him back up again soon.

THERE ARE 360 individual parts inside Cozmo

1.4 MILLION lines of code have been used to write Cozmo's brain

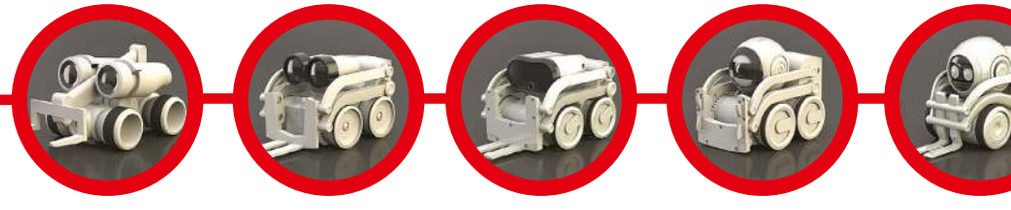
A familiar face
The camera and processor allow Cozmo to recognise and remember people's faces, and he can recognise pets, too!

No unused space
Aside from a pocket of air surrounding the speakers in Cozmo's head, the rest of the robot is densely packed.

Vision and sensors
By using advanced computer code that's able to interpret sensory information, Cozmo is able to map his surroundings and navigate them independently.

The evolution of Cozmo

Over 40 iterations of Cozmo have been created. With the guidance of former Pixar animators, the robot became smaller, gained treads and later transformed from a biclops to a screen with digital expressions.



"Cozmo has been meticulously programmed with flexible behaviours"

The intelligent machine

Discover the engineering and computing that makes Cozmo such an engaging companion

128 x64
The resolution display of Cozmo's screen, which he uses to show his range of emotions

Cozmo's main play toys are Interactive Power Cubes

Animatronics
Cozmo uses a combination of facial expressions, sounds and movement to display his emotions.

Motors
Cozmo is equipped with four motors that power the movement of his treads, arms and head.

Cozmo requires nearly 50 gears to drive, turn and flip

Made for mischief
Cozmo uses his arms to stack and topple over his toy blocks, and raises them in celebration after he wins a game.

Curious Cozmo will raise his arms and a questionable eye when tackling his blocks

New software that will allow Cozmo to form unique relationships with each user is being developed

A big future

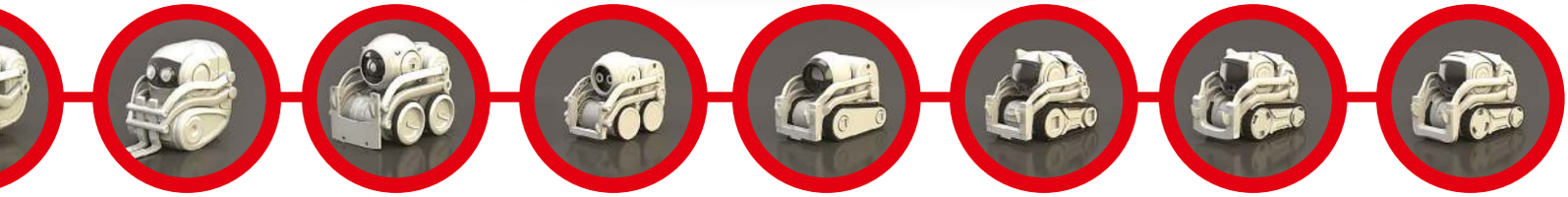
Cozmo has already become more than just a toy. In fact, he's already become an actor in several YouTube videos, but Anki believe he has an even greater destiny. With the Cozmo Software Development Kit (SDK), Anki have allowed coders to write new personality traits and improvements for their Cozmo units using a common coding language.

Excitement is already building for the potential benefits these changes could bring, and research institutions are also putting Cozmo to work in their machine learning and artificial intelligence programming studies. The robot may soon find its way into schools as an educational tool for coding as well.

Anki themselves are also constantly writing upgrades for Cozmo's software, including an update that will enrich the personal relationships that can be established between Cozmo and the individuals he recognises. Whichever direction this progress moves in, it will be very interesting to see what Cozmo grows up to become.

Over **200** assembly steps are involved in building each unit

Cozmo also comes in a collector's edition with a different colour scheme



Rubik's cube

The iconic toy and famously difficult puzzle that inspired a generation

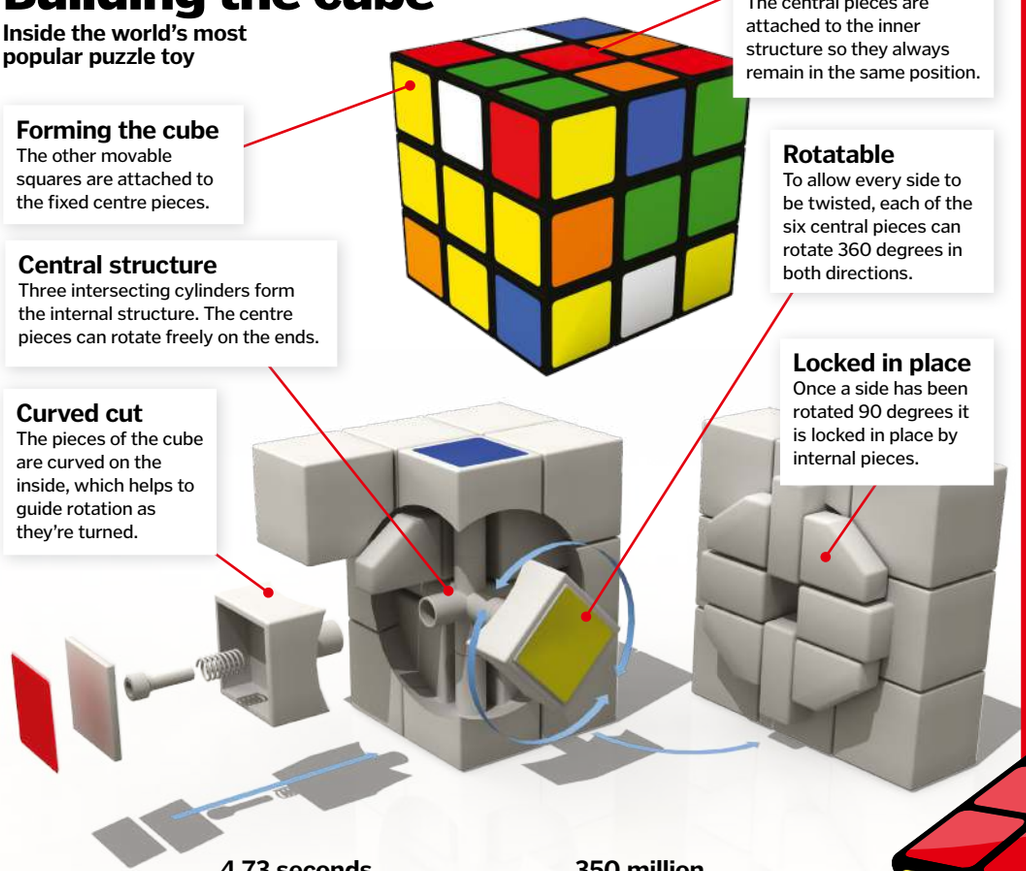
To those familiar with the ingenious design of the Rubik's cube, it may come as no surprise that this tricky structure was invented by an architect. In 1974, a young Hungarian professor named Erno Rubik invented a model toy that was simultaneously simple and notoriously complex. In fact, it proved so difficult to solve that even its creator couldn't do it at first!

Consisting of six sides that could be fully rotated, allowing the nine coloured squares on each face to be scrambled into hundreds of combinations, it was so clever it looked like a product of wizardry. With a similar reasoning on his mind, Rubik originally dubbed his creation the 'Magic Cube'. But when distributed to the mass market some time later it was renamed as the Rubik's cube, and an icon was born.

The Rubik's cube's novelty lies in its three-dimensional rotatability. Players are able rotate any side of any face they choose both clockwise and counter-clockwise, organising the typical 3x3 dimensional cube into any one of its several quintillion possible combinations. The goal – after scrambling – is to restore a single colour onto each face of the cube. Today, the Rubik's cube has evolved to include 2x2, 4x4 and 5x5 variants and has even spawned a competitive sport in the form of 'speedcubing'. This puzzle remains one of the most engaging around, and if you want to challenge your logic and patience, there's no better tool for the test.

Building the cube

Inside the world's most popular puzzle toy



Fixed in place
The central pieces are attached to the inner structure so they always remain in the same position.

Forming the cube
The other movable squares are attached to the fixed centre pieces.

Rotatable
To allow every side to be twisted, each of the six central pieces can rotate 360 degrees in both directions.

Central structure
Three intersecting cylinders form the internal structure. The centre pieces can rotate freely on the ends.

Locked in place
Once a side has been rotated 90 degrees it is locked in place by internal pieces.

Curved cut
The pieces of the cube are curved on the inside, which helps to guide rotation as they're turned.

4.73 seconds
The fastest time taken to solve a 3x3 Rubik's cube

350 million
Rubik's cubes have been sold worldwide to date

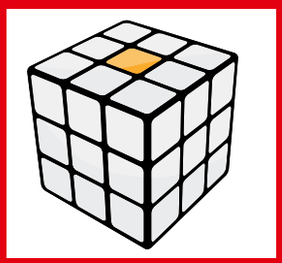
5
Record number of Rubik's cubes solved underwater in a single breath

43,252,003,274,489,856,000
The total possible number of Rubik's cube configurations

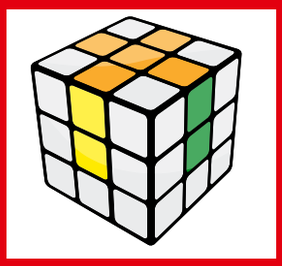
5.6 millimetres
Size of the world's smallest functioning Rubik's cube

A curious cube

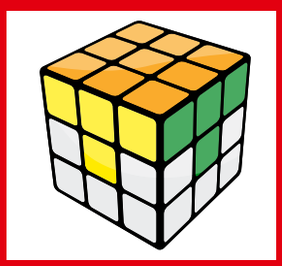
How to work out Rubik's riddle



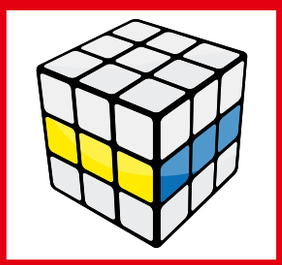
1. Pick a starting side
Choose a colour (going by the central square) and mark that as the top layer.



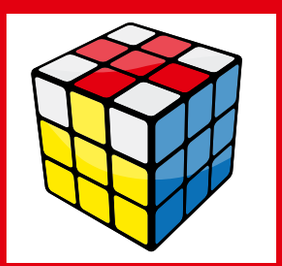
2. Make a cross
Find other squares of that colour and align them as the middle squares of the bottom layer, then rotate 180 degrees.



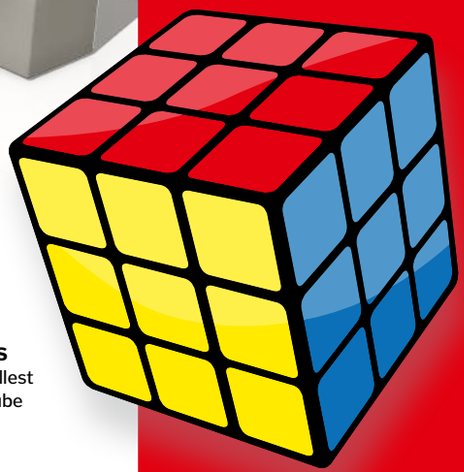
3. Fix the corners
Find squares of your colour that are in the corners and rotate them onto the top layer.



4. Complete middle layer
Flip the completed side so it's on the bottom then align the middle layer (going by the square located in the centre of the faces).



5. Create the top cross
For the top layer, make an L shape in the top-left corner before aligning the other two middle squares.



6. Fix top corners
Rotate the top layer so it has a corresponding colour in the bottom right corner. Twist the cube's right side and bottom side until the corners are all aligned. Then twist the top and bottom layers to finish!

1.5 million
more people will be within 45 minutes of central London when the project is completed

Crossrail will reduce journeys between the City and Heathrow from around 1 hour to **34 minutes**

CONSTRUCTING CROSSRAIL

The engineering behind the new high capacity rail line that will pass under London

If you've spent any time in certain parts of London over the past few years, you'll have noticed an unusually large number of construction sites. While civil engineering and building works have always been a fact of life in England's capital, much of the current work is associated with Crossrail, Europe's biggest infrastructure project and one of the largest ever undertaken in the UK. Here, we take a look at this ambitious project and delve into some of the technologies that are being used to build this important new rail link. We'll also look at the new rolling stock and station facilities that will cater for 200 million passengers annually.

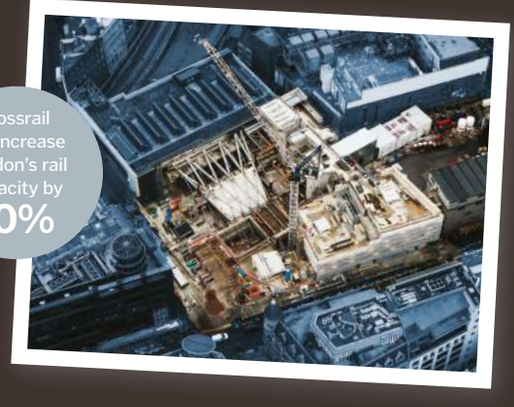
Officially, Crossrail has been renamed and is now called the Elizabeth Line. It will be shown on London Underground maps as a purple and white line, although it won't actually form part of the Underground network. It will be operated by Transport for London (TFL) and will link Reading and Heathrow in the west through 21 kilometres of twin-bore tunnels under central London to Shenfield and Abbey Wood in the east, a total distance of 118 kilometres. There will be 40 stations, ten newly built and the others upgraded to take the new trains. Some of these will connect with London Underground and other rail services.

Construction started in 2009 and, as of May 2017, the railway is 80 per cent complete, with the first services, between Heathrow and Paddington, expected to start in May 2018. The entire line will be open by December 2019.

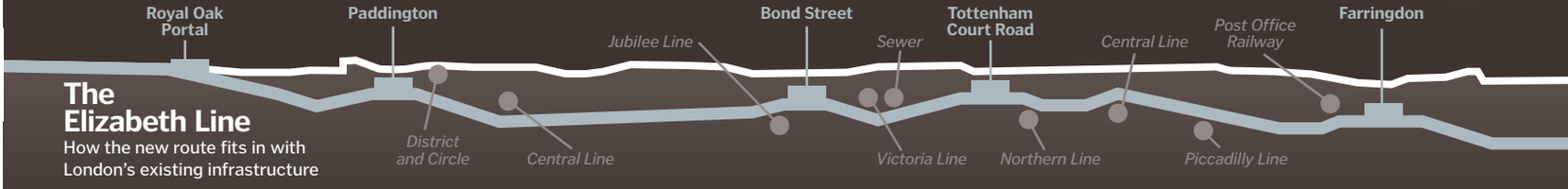
One of the most challenging parts of this ambitious project was boring the 42 kilometres of 6.2-metre-diameter tunnels under Central London. This feat was accomplished using eight giant tunnel boring machines (TBMs). Each worked 24 hours a day, seven days a week, and, as a result, completed their herculean task in three years, finishing in May 2015.

Since only the central portion of the Elizabeth Line is underground, an obvious way of launching the TBMs into the ground was at the points where the line goes below the surface. However, logistics dictated that this wasn't always possible, so in several cases the 550-ton, 150-metre-long boring machines had to be lowered underground in sections and then reassembled. The TBMs were hoisted into

The Farringdon construction site, pictured earlier this year, is just one of many Crossrail sites across London



Crossrail will increase London's rail capacity by **10%**



The Elizabeth Line
How the new route fits in with London's existing infrastructure

specially built shafts up to 30 metres in diameter and 44 metres deep using one of the largest cranes in Europe. In the case of the construction site at Canning Town in the East End, a high angle conveyor was used to carry millions of tons of the excavated material up a shaft. It was then loaded directly onto ships and transported to Wallasea Island in Essex, where it is being used to help create a new 600-hectare RSPB nature reserve.

The ground below Central London is surely one of the most congested subsurface areas in the world. In planning the route for the Elizabeth Line consideration had to be given to avoiding London Underground and other rail tunnels, sewers, electricity and telephone cables and so much more. Then the tunnel boring machines had to be accurately steered so as not to deviate from their planned routes. The satellite signals that drive GPS systems, which can provide millimetre accuracy on the surface, are not available underground. Yet in at least one location, the Tottenham Court Road Station, the new tunnel had to run within 80 centimetres of a Northern Line tunnel. This was achieved using the tunnel boring machines' laser guidance systems, which ensured that each tunnel ended up within a few millimetres of its intended position.

200,000 concrete segments were used to line the tunnels

However, even if all the tunnels were accurately drilled according to the plan, there was still a risk that surface buildings or London Underground tunnels could be adversely affected as a result of the new

Meet the fleet

These vehicles each play vital roles in the construction process

Concreting train
The concreting train lays a concrete slab in the bottom of the tunnel to act as a base for the track.

Concrete shuttle
Where room is limited, a concrete shuttle is used instead of the concreting train. It carries pre-mixed concrete rather than dry material.

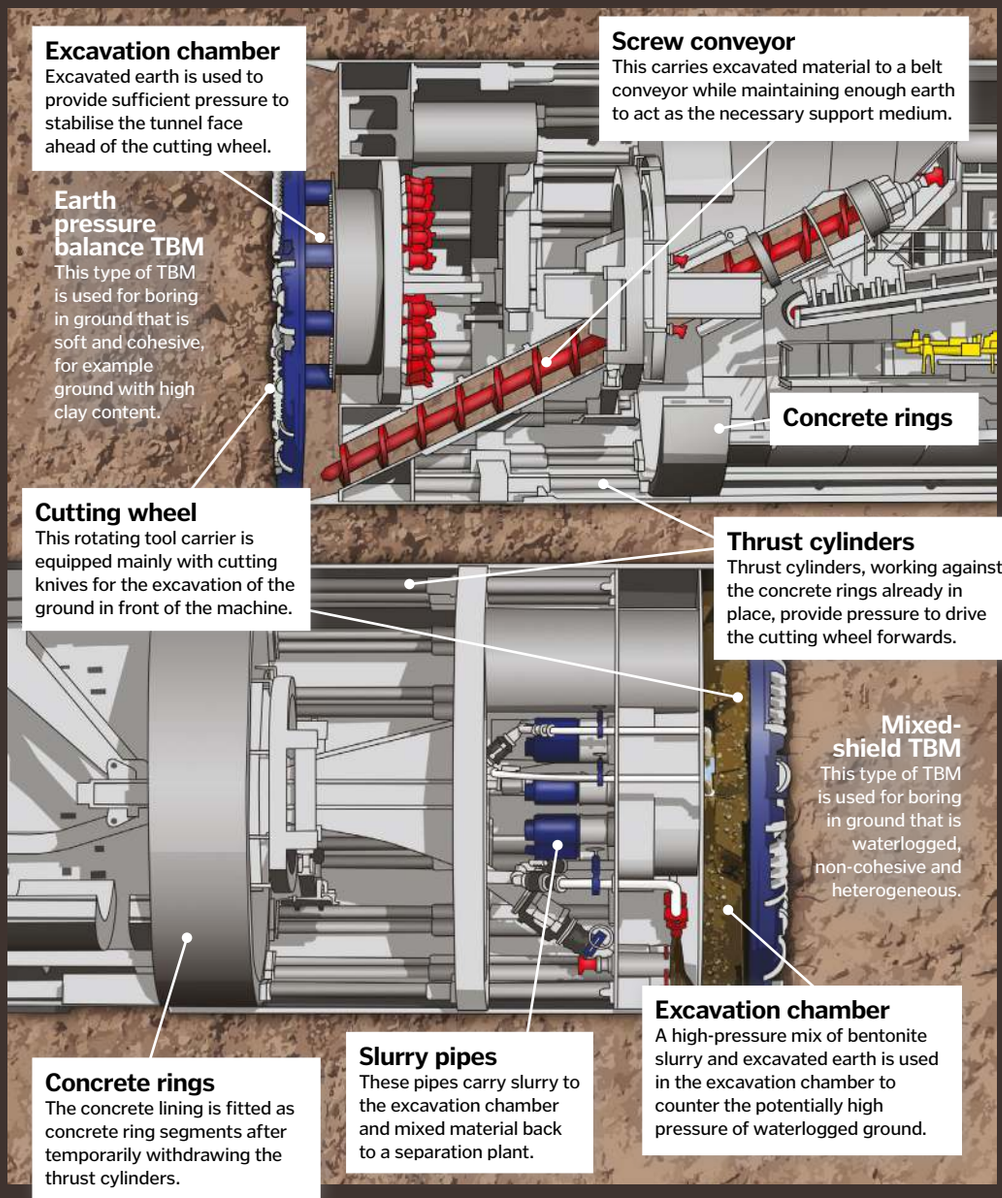
Multi-purpose gantries
These gantries are used to alternately lay concrete sleepers and track sections, welding each section of track to the previous one.

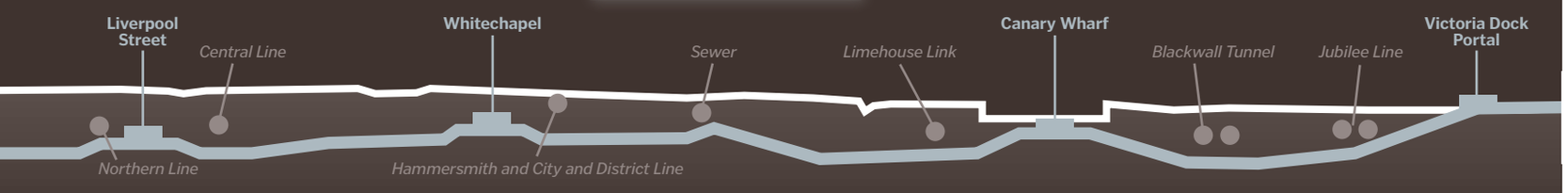
Drilling rig
Holes are drilled into the tunnel walls to support cabling, walkways and fire mains, plus the electricity lines that power the trains.

Construction trains
A fleet of construction trains is used to carry sleepers, rails and other materials into the tunnels.

Tunnel boring machines

How the earth pressure balance and mixed-shield tunnel boring machines differ





large-diameter tunnels weakening the ground and causing settlement. This was avoided using the technique of compensation grouting in particularly sensitive areas. To achieve this, nearby shafts were sunk and then an array of small-diameter boreholes were drilled in a fan arrangement from the shafts into the surrounding rock. Then buildings that were considered to be at risk were fitted with prisms, while others were fitted with accurate surveying instruments known as total stations. The total stations automatically scanned for visible prisms and recorded their position in real-time during drilling operations. If any slight movement was detected, a cement-type slurry called grout was injected into the boreholes, from where it migrated into fissures in the surrounding rock, thereby providing the necessary additional strength.

Boring the tunnels and building the stations is one thing – equipping them with the necessary communications and power infrastructure is quite another. Unbelievable as it might sound for a line 118 kilometres in length, the network will have a reported 15,000 kilometres of cabling, most of which will be concerned with operating the railway itself, while some will provide passengers with WiFi and 4G connectivity. But if you thought that Crossrail represents the pinnacle of engineering achievement in London's transport system, think again.

15,000 people

have worked 100 million hours on Crossrail

As Crossrail is nearing completion, talk has turned to yet another railway system to weave its way under the capital. Called Crossrail 2, the new railway (if it comes to fruition) will connect Surrey and Hertfordshire via Central London. It will have almost twice the length of large-diameter tunnelling as Crossrail and no doubt employ even more advanced technology. Don't hold your breath though – services aren't expected to start until 2033.

This salt marsh, part of the Wallasea Island nature reserve, was created using earth excavated from Crossrail tunnels

Floating tracks

Special tracks will be used in a a couple of sensitive areas. So-called 'floating track (light)' will reduce noise pollution and vibrations to hotels and recording studios in Soho, while 'floating track (heavy)' will provide enhanced protection for the Barbican Theatre near Farringdon.

In each case, the tracks float on a combination of elastomer rubber bearings and heavy duty springs. However, because of the space occupied by these additional fixtures, the concrete slabs on which the rails are mounted have had to be reduced in thickness. To ensure that the shallower slabs are sufficiently strong and will effectively minimises noise and vibration, a special type of concrete called Magnadense is used. Twice as dense as ordinary concrete, Magnadense uses an aggregate manufactured from iron oxide.

Tracks in sensitive areas float on rubber and springs to reduce noise and vibrations

Class 345 trains, produced by Bombardier in Derby, will run on the Elizabeth Line

The new trains

A fleet of brand new trains, built by Bombardier in Derby, will provide new levels of convenience and comfort, as well as carrying more passengers than trains on the London Underground. At 200 metres long and comprising nine fully-interconnected walk-through carriages, each train will be able to carry 1,500 people. As well as offering WiFi and 4G mobile connectivity, the trains will show real-time travel information and feature intelligent lighting and temperature control. The trains will employ regenerate braking, passing electricity back to the power supply when braking, meaning they will use up to 30 per cent less energy than conventional trains.

Unearthing the past

Increasingly, archaeological investigations form part of large civil engineering and building works, so it's not surprising that a project the size of Crossrail has unearthed some finds. Indeed, the Elizabeth Line runs through some of the capital's most important historical areas.

So far, over 100 archaeologists have discovered tens of thousands of items from 40 sites, representing 55 million years of history. Many of the finds are now on display at the Museum of London Docklands. Discoveries near Liverpool Street Station included the foundations of Broad Street railway station, the former Bedlam burial ground, a Roman road and the Walbrook, one of London's lost rivers. Perhaps most significantly, though, was a mass grave which is thought to contain the remains of victims of the Great Plague.

This suspected 1665 Great Plague pit was unearthed at the Liverpool Street site

The new stations

The innovative station facilities that will improve the passenger experience when travelling on Crossrail

£42 billion
The estimated amount that Crossrail will bring to the UK economy

Canary Wharf station
Canary Wharf might be the jewel in the crown of Crossrail, but some of the innovative features are also being employed at other new stations.

Parkland
The top floor houses a roof garden. The roof opens in the centre to allow light and rain for natural irrigation.

Step-free access
All Crossrail stations will have lifts as well as escalators to provide step-free access from street to train.

Escalators
No fewer than 17 escalators connect the retail floors with the station platform.

Retail and leisure
Four flours of the development, occupying nearly 10,000 square metres, are dedicated to retail and leisure facilities.

The Queen meeting Crossrail workers during a visit to the Bond Street construction site

Concourse
The 185-metre-long concourse provides a visual connection with the platforms below via large openings between the two floors.

On the fastest day during construction, a single TBM bored
72m

Screens
Full height platform edge screens will separate passengers from the trains until they come to a halt. This safety feature also helps prevent drafts on the platform, as well as reducing track cleaning and air conditioning costs.

Platforms
The platforms are 240 metres long – considerably bigger than London Underground platforms – to accommodate the longer trains.

Mayflower Autonomous Research Ship

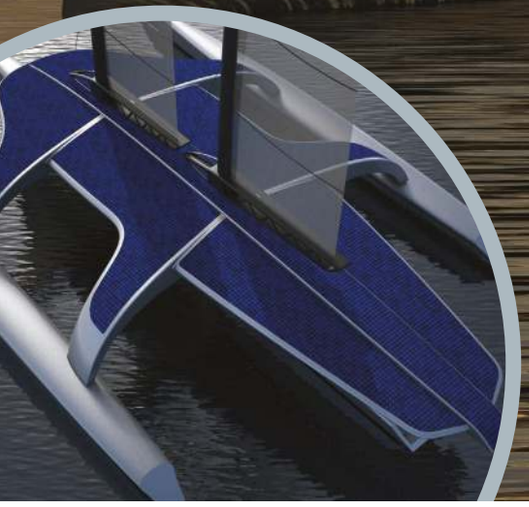
How will the world's first full-sized, fully autonomous unmanned ship make it across the Atlantic Ocean?

Materials
The hull is made from a glass-aramid-foam composite and the deck is built from carbon and nomex materials.

Electric motor
Energy from the solar panels is stored in batteries and powers the electric motor, which creates a top speed of 12.5 knots.

Payload bays
Scientific instrumentation, including Underwater Autonomous Vehicles, can be stored aboard and remotely deployed to gather data.

Trimaran design
The three-hull configuration allows waves to break through the vessel, reducing impact for efficient low-speed sailing.



MARS will be 32.5 metres in length and 16.8 metres wide

In 2020, 400 years after the original Mayflower embarked on its historic journey from Plymouth, Britain, to Plymouth, US, another groundbreaking vessel will follow in its wake.

The Mayflower Autonomous Research Ship (MARS) is a multimillion pound project being developed by the UK's Plymouth University, autonomous craft specialists MSubs, and yacht designers Shuttleworth Design. Unlike its namesake, it will be captained remotely so there will be no crew on board, and in addition to wind power it will also be propelled by energy from the Sun.

As well as marking an important maritime anniversary, MARS will serve as a state-of-the-art research platform capable of conducting numerous experiments at sea. Its cargo will include a variety of drones and scientific instruments that will gather meteorological, oceanographic and climate data that can be transmitted ashore for analysis, and the ship itself will serve as a test bed for new navigation software and renewable energy technology. It is also hoped that the project will provide live educational resources to students around the world as they follow the ship's record-breaking maiden voyage across the Atlantic Ocean.

The crossing could take as little as seven to ten days with optimal conditions, but as there is no need for it to stop to refuel or replenish a

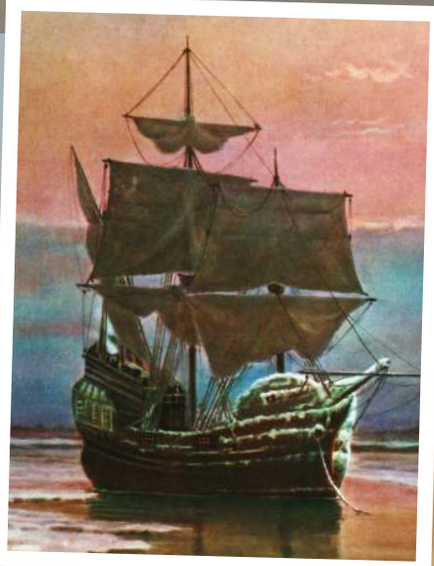
Aboard the MARS

The groundbreaking design of the crewless laboratory at sea

The original Mayflower

In September 1620, 102 passengers boarded a merchant ship called the Mayflower in Plymouth, Britain, ready to start a new life across the Atlantic. The ship was usually used to transport wine and dry goods, but for this trip, a group of Protestant Separatists were the cargo. Disgruntled with the Church of England, which they believed to be corrupt, they hoped to find religious freedom and establish a new church in the New World.

Their journey had originally begun a few months earlier when the Mayflower set sail alongside the Speedwell, but both ships had to return to port when the Speedwell sprung a leak. The delay meant the Mayflower eventually had to make its crossing during storm season, resulting in rampant seasickness and one passenger being swept overboard. However, after two months, the Pilgrims made it to America and set up their own colony, which they named Plymouth.



The Mayflower played an important role in the European colonisation of what later became the United States

Solar cells
When there is not enough wind, solar power can be used to give the vessel unlimited range.

"MARS will serve as a state-of-the-art research platform"

Sails
The two soft sails enable top speeds of 20 knots and can be used in three configurations for varying wind speeds.

Outer hulls
These hulls help maintain balance and are slightly elevated so they can skim the water to reduce resistance.

Centre hull
As there is no need for accommodation, this hull can be kept low to the water for greater stability.

It is hoped that MARS will contribute to advancements in marine technology

crew, it may be at sea for seven to ten months in order to collect as much data as possible.

Construction of MARS is expected to take two years, with trials planned for 2019. As there will be no one on board to repair the vehicle if it encounters problems, engineers must make sure it is as robust as possible before its mission. After completing its Atlantic crossing it will then circumnavigate the globe before being made available for scientists to hire for projects.

How tyres are made

What it takes to produce road-ready wheels

The very first road vehicle wheels, used for carts and wagons, were made solely of metal or wood. It wasn't until the mid-1800s with the discovery of rubber that they were first covered in materials resembling the car tyre we know today. Though these remained simple rubber circles until the early 20th century, this era saw the advent of inflated rubber tyres to better absorb bumps and also tread to increase traction. Today, the modern tyre requires more than 200 different materials including a pigment (in the form of carbon black) and other natural and synthetic additives including vulcanising agents, sulphur, silicone and plasticisers.

Though tyres are designed to be extremely tough and durable, their importance and ingenuity is often overlooked. A safe tyre must have the capacity to bear an incredible amount of weight while enduring the high pressure of the air inside and resisting puncture from the outside. The key to this strength is the process of precisely layering the tyre components and reinforcing them with metal components. A typical bead wire alone can comfortably carry a load of up to 1,800 kilograms, meaning an average set of tyres can support over 14,400 kilograms. The fibrous layers of cording made from Kevlar or steel, crucial to resisting pressure and thick layers of rubber tread, significantly reduce the risk of puncture.

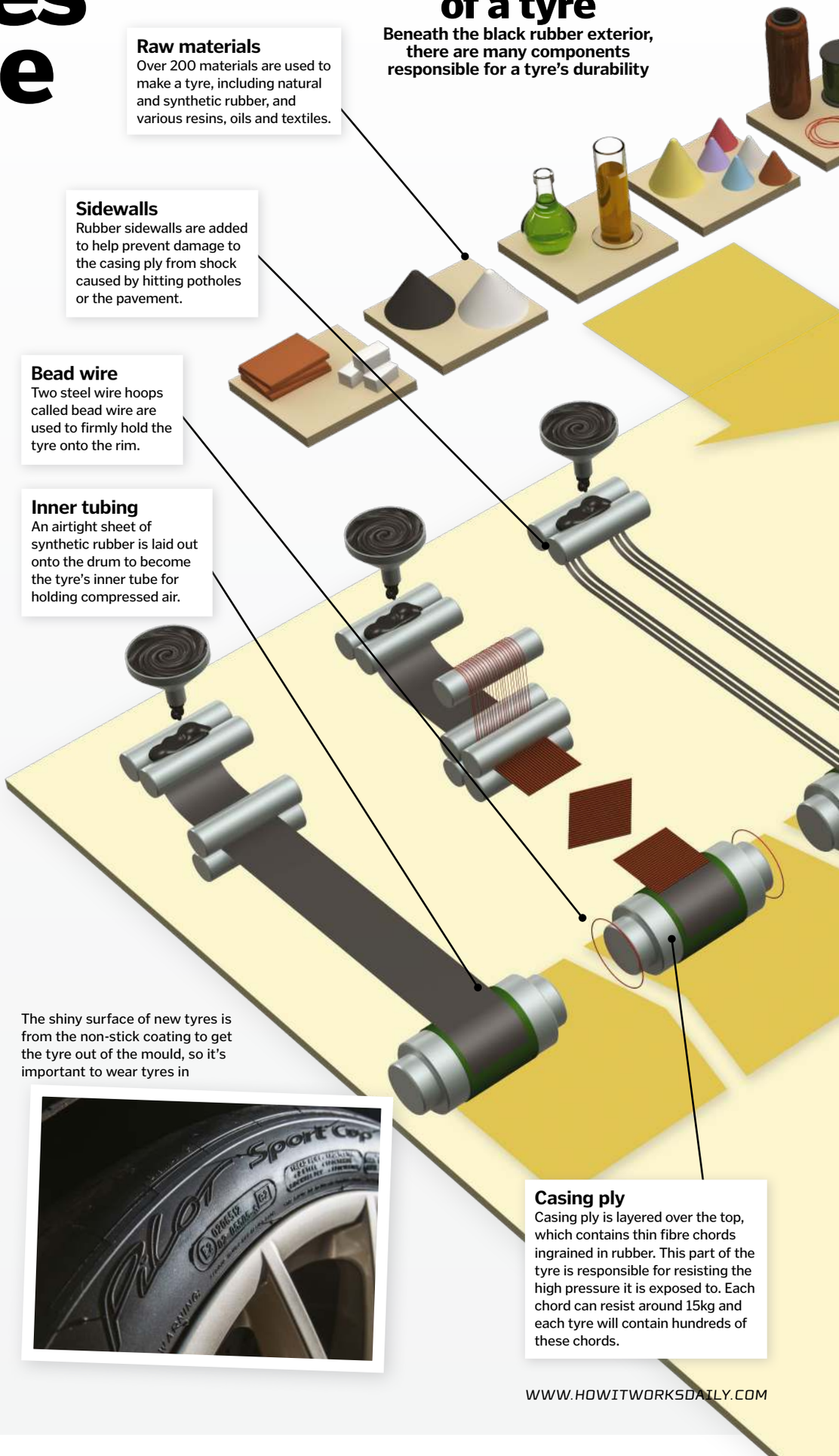
The building process relies on a rotating tyre-building drum with a flexible centre to move the edges together after the layers have been wrapped around it. Once on the drum the tyre is placed into a mould to blend together the components under extreme heat and pressure.

Though the basic principles and ingredients remain the same, there are many different types of tyre for different road conditions. The most common variants are summer and winter tyres. Winter tyres remain soft at lower temperatures to prevent them from hardening and becoming brittle in the cold, in addition to their more complex tread pattern that allows better traction and faster braking.

More recently, there has been added focus on even more safety features, including tyres with a mechanism to prevent them going entirely flat for up to 80 kilometres after a puncture.

Anatomy of a tyre

Beneath the black rubber exterior, there are many components responsible for a tyre's durability



Raw materials

Over 200 materials are used to make a tyre, including natural and synthetic rubber, and various resins, oils and textiles.

Sidewalls

Rubber sidewalls are added to help prevent damage to the casing ply from shock caused by hitting potholes or the pavement.

Bead wire

Two steel wire hoops called bead wire are used to firmly hold the tyre onto the rim.

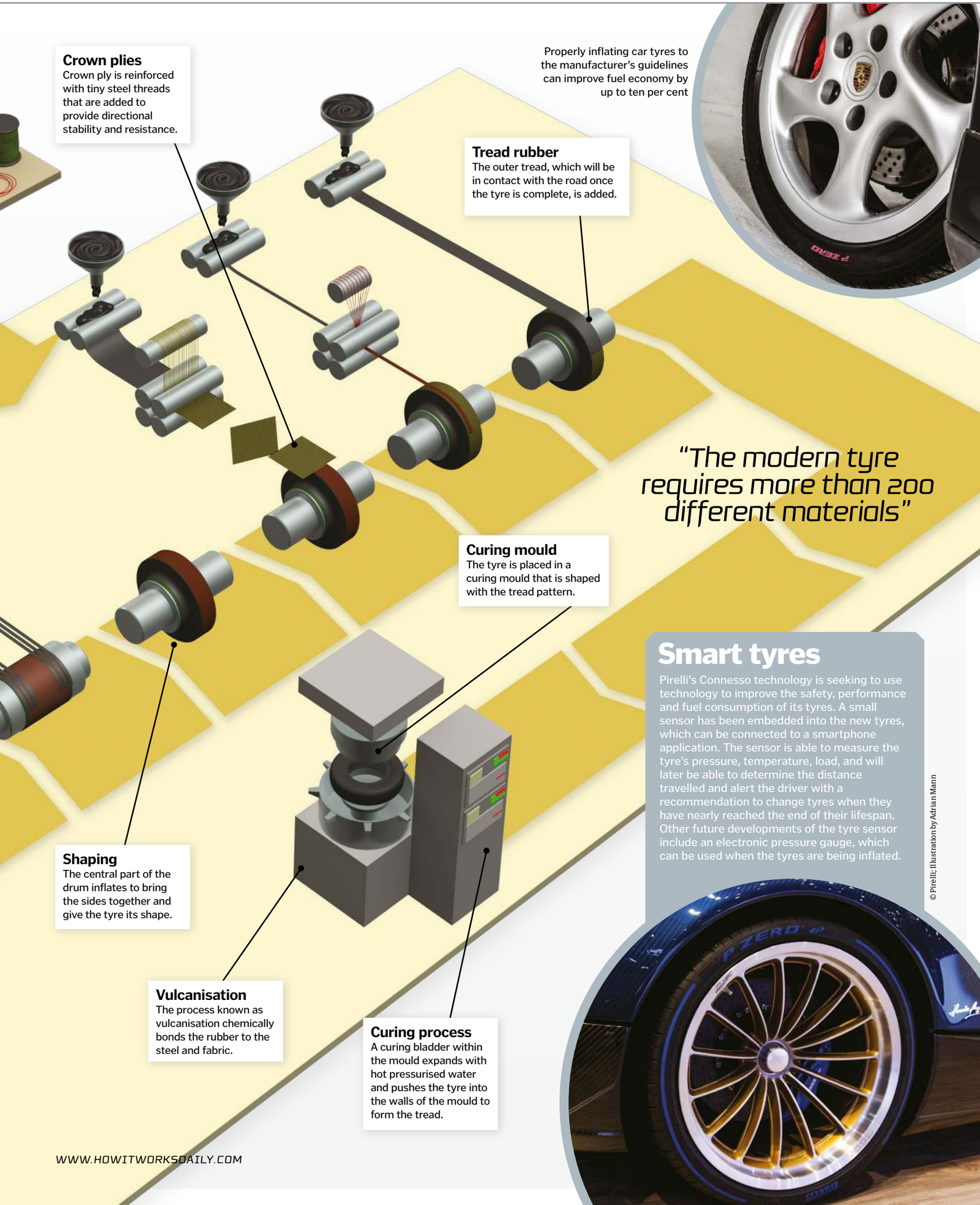
Inner tubing

An airtight sheet of synthetic rubber is laid out onto the drum to become the tyre's inner tube for holding compressed air.

Casing ply

Casing ply is layered over the top, which contains thin fibre chords ingrained in rubber. This part of the tyre is responsible for resisting the high pressure it is exposed to. Each chord can resist around 15kg and each tyre will contain hundreds of these chords.

The shiny surface of new tyres is from the non-stick coating to get the tyre out of the mould, so it's important to wear tyres in



Crown plies
Crown ply is reinforced with tiny steel threads that are added to provide directional stability and resistance.

Tread rubber
The outer tread, which will be in contact with the road once the tyre is complete, is added.

Curing mould
The tyre is placed in a curing mould that is shaped with the tread pattern.

Shaping
The central part of the drum inflates to bring the sides together and give the tyre its shape.

Vulcanisation
The process known as vulcanisation chemically bonds the rubber to the steel and fabric.

Curing process
A curing bladder within the mould expands with hot pressurised water and pushes the tyre into the walls of the mould to form the tread.

Properly inflating car tyres to the manufacturer's guidelines can improve fuel economy by up to ten per cent

"The modern tyre requires more than 200 different materials"

Smart tyres

Pirelli's Connesso technology is seeking to use technology to improve the safety, performance and fuel consumption of its tyres. A small sensor has been embedded into the new tyres, which can be connected to a smartphone application. The sensor is able to measure the tyre's pressure, temperature, load, and will later be able to determine the distance travelled and alert the driver with a recommendation to change tyres when they have nearly reached the end of their lifespan. Other future developments of the tyre sensor include an electronic pressure gauge, which can be used when the tyres are being inflated.

Hot air balloons

How these big balloons rely on the principles of physics to fly

Hot air balloons were first invented in Paris in 1783 and were the first transport to allow humans to travel by air. Their design has remained similar over the centuries with a fabric 'envelope' to contain the hot air with a vent in the top and a basket underneath for the passengers.

Hot air balloons float due to the heated air inside the envelope having a lower density than the colder air outside. In the same way that a boat is supported by water on the ocean, it is cold air supporting a hot air balloon.

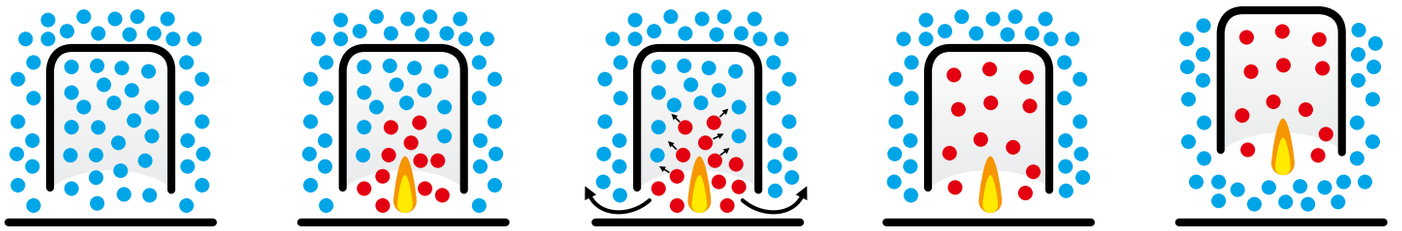
Operating a hot air balloon requires specialised knowledge and skill. A pilot must have an understanding of the wind directions at a different altitude, as the only method to steer is by catching these directional winds. By controlling the amount of hot air within the balloon a pilot can change the vertical direction either up or down.

For the vessel to be moved upwards, the pilot fires up a propane gas burner and can change the speed of ascent by controlling the strength of the flame. At the very top of the balloon is a self-sealing flap that can be controlled by the pilot by a long chord. This mechanism allows the pilot to let the hot air escape at a steady rate to either slow the ascent or cause the balloon to start descending back towards the ground. By moving the balloon up and down it is possible for the pilot to catch different winds moving in different directions to navigate the skies.

Floating physics

A Chinese lantern is a simple model for understanding the physics of hot air balloon flight

COLD AIR PARTICLE **HOT AIR PARTICLE**



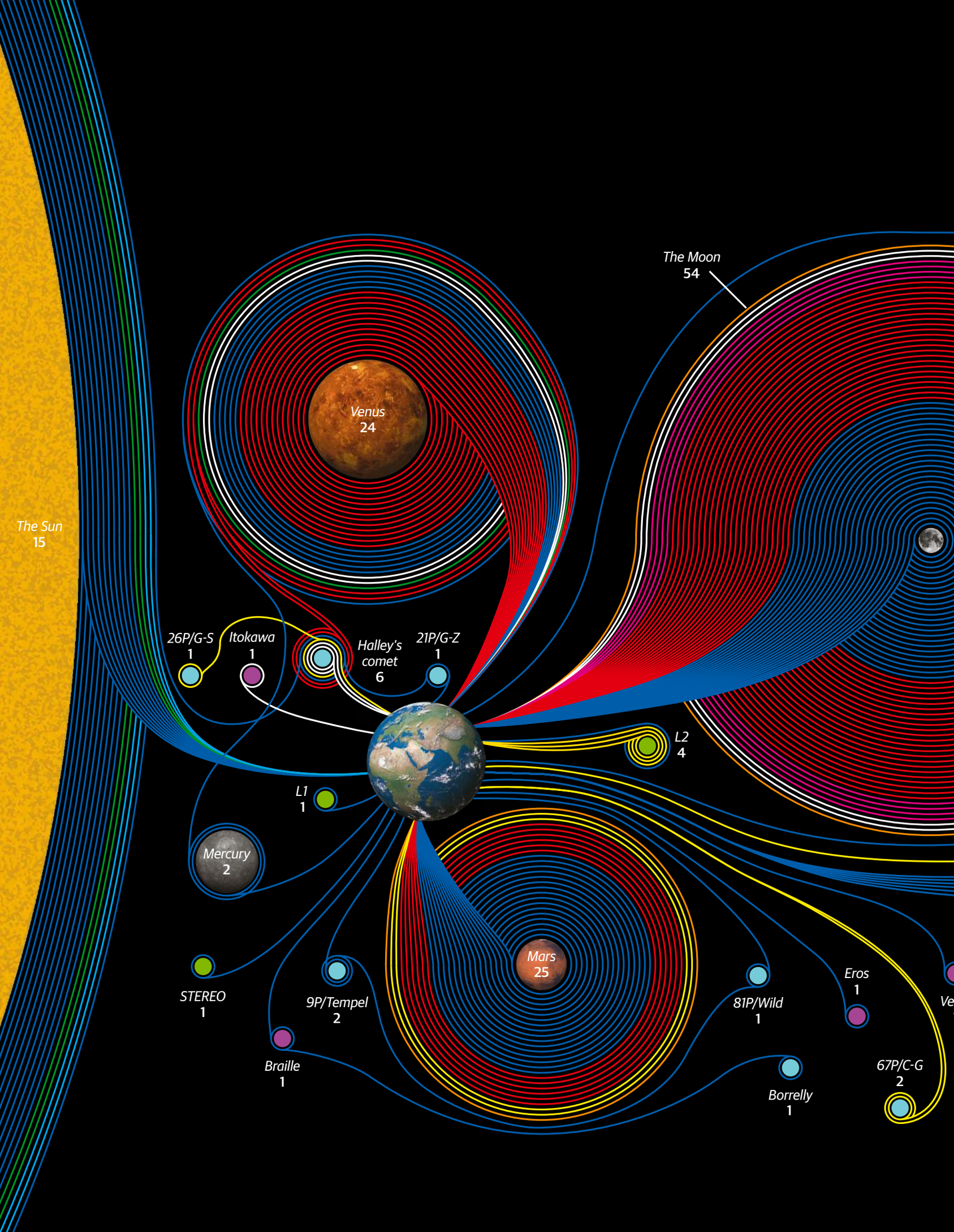
1 Uniform temperature
Without a flame, the air molecules inside and outside the lantern are the same temperature.

2 Flame
When the burner is lit within the lantern, chemical energy in the fuel is transferred to kinetic energy in the air.

3 Heating up
The hot air molecules rapidly spread up and out, displacing the cold air molecules, which are either heated or ejected.

4 Temperature difference
The cold air molecules are pushed out of the lantern by the expanding volume of hot air.

5 Density
The expansion of hot air means it is less dense than the cold air, inflating the balloon and causing it to rise upward.


The Sun
15
Venus
24
The Moon
54
26P/G-S
1
Itokawa
1
Halley's comet
6
21P/G-Z
1
L2
4
L1
1
Mercury
2
Mars
25
STEREO
1
9P/Tempel
2
Braille
1
81P/Wild
1
Eros
1
Borrelly
1
67P/C-G
2

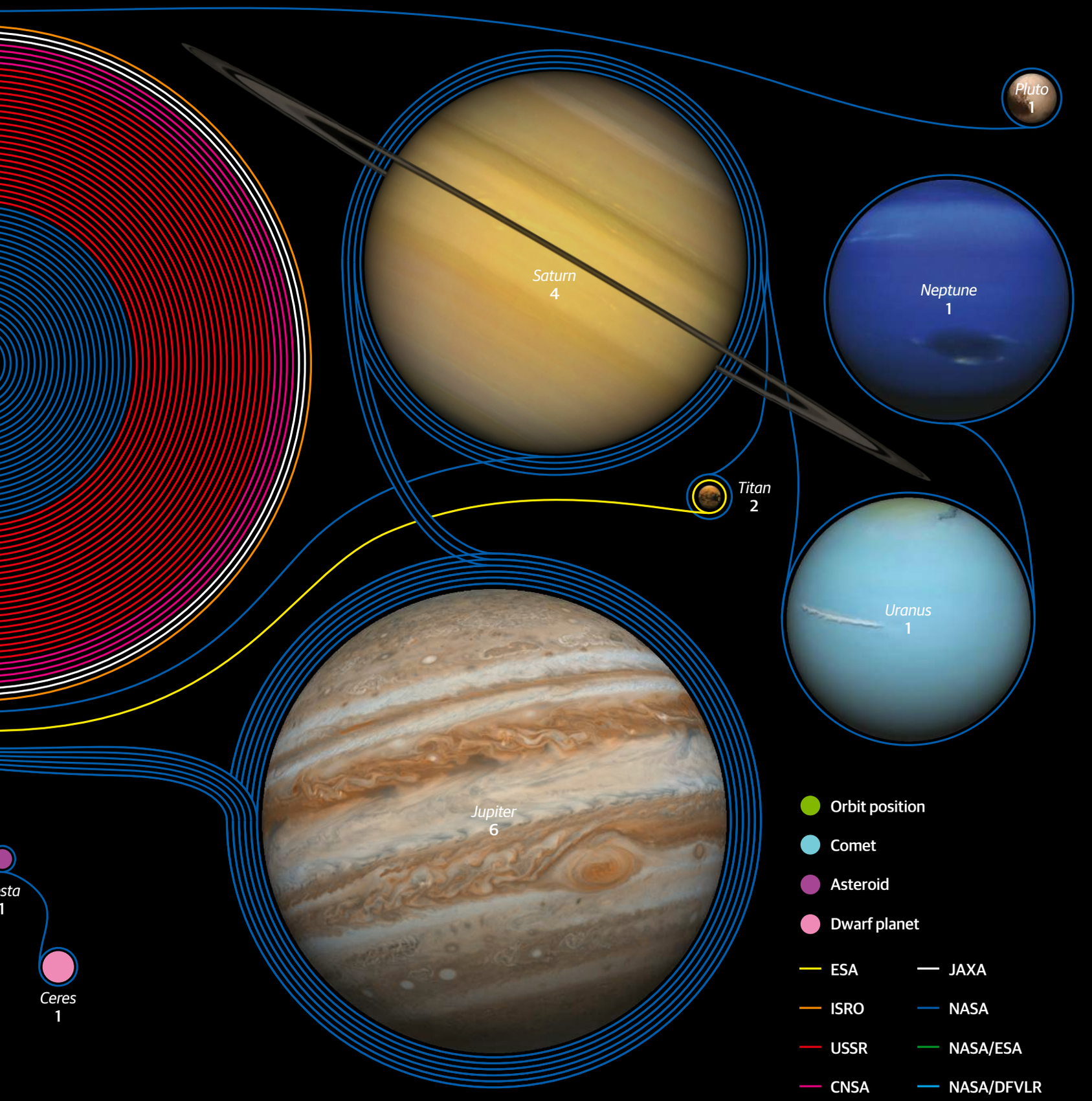

WW2 Wehrmacht soldier
20th century
WW2 Soviet sniper
20th century
1st Duke of Norfolk
15th century
Greek hoplite
7th-4th century BCE
WW1 Australian Light
Horse Regiment
20th century
WW2 US paratrooper
20th century
Navy seal frogman
20th century
Revolutionary redcoat (British)
18th century
Second Franco-Mexican War
Mexican Army regular
19th century
WW2 British commando
20th century
Revolutionary bluecoat
(American)
18th century
French Foreign Legion pioneer
19th century
Ottoman janissary
14th-19th century
Peninsular War Spanish guerilla
19th century
Mysore Indian Army lancer
20th century
WW1 Imperial
German soldier
20th century
16
Gurkha
19th century
- present day

HOW IT WORKS

LEGENDARY WARRIORS

VOL 2

HOW MANY SPACECRAFT HAVE EXPLORED THE SOLAR SYSTEM?



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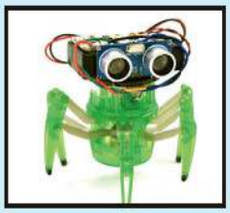
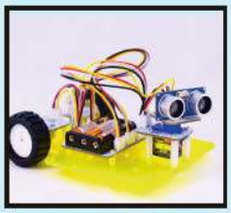


Turn a toy into a fully programmable 'bot in

Robot Brain Surgery

Move over Bond ... make your own gadgets in

Gadget Factory



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THE FUTURE OF MEDICINE

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Medical science has produced some incredible solutions to challenging problems over the decades, from antibiotics to fight bacterial infection to imaging technologies to look inside patients without using a knife. It's hard to predict what will happen next, but science has recently opened some really exciting doors to the future of medical treatment.

Medicine is no longer just about biology and drugs. Computing, engineering, nanotechnology, quantum physics and many more disciplines are flowing over into medical technology and providing brand new solutions to age-old problems.

In the hospitals of the future augmented reality could allow surgeons to see through their patients, and contact lenses could monitor blood sugar for diabetics. Prosthetic limbs linked directly to the nervous system could allow amputees to move and feel just by thinking, while 3D printers could be utilised to create custom medical kit, or even fully working replacement organs, on demand.

We are learning how to retrain our own immune systems to fend off deadly diseases, and we are developing technology that could allow our own genetics to be tweaked and changed on the go. The scientific community has access to a massive and rapidly expanding pool of data from patients the world over, and as we dig deeper into the biochemistry of illness, new ways to precisely treat disease are set to appear.

One day wearable tech and at-home test kits could monitor for the first signs of sickness, and custom treatments might be delivered based on our own unique genetic and biochemical fingerprints, minimising side-effects and maximising our chances of recovery.

How germs spread

Body fluids

Blood, saliva, semen and breast milk can all carry disease

Liquids provide an excellent way for pathogens to travel from one place to another. Precautions are always taken when dealing with bodily fluids in hospitals and labs because contaminated fluids can transmit diseases like mumps, hepatitis and HIV.

Skin to skin contact

Some infections are quickly spread by direct contact

Chickenpox, cold sores, head lice and warts can all be transmitted by touching someone with the infection; the viruses, bacteria or parasites simply move from one person to another. Some of these examples can also survive on inanimate surfaces for a short time.

Food and drink

Contaminated food and drink carry pathogens into the gut

The acidity of the stomach provides some protection against infection, but it can't stop everything. Pathogens enter through the mouth and either set up home in the digestive tract or move into the body through its walls.

Droplets

Pathogens can be transmitted short distances by drops of liquid in the air

Tiny drops of fluid released by a cough or a sneeze travel around a metre before they settle onto door handles, surfaces and skin. It's an easy way for respiratory infections to spread. Examples include colds, flu and rubella.

Preventing history's biggest killers

Vaccinations teach the immune system how to fight before it encounters the real disease

Our natural defence against disease is our immune system. This army of cells work together to patrol the body and destroy anything that shouldn't be there. It's split into two parts: a fast-response 'innate' system that wages war at the first sign of trouble and a slow, specialised 'adaptive' system that delivers a stronger and more focused attack.

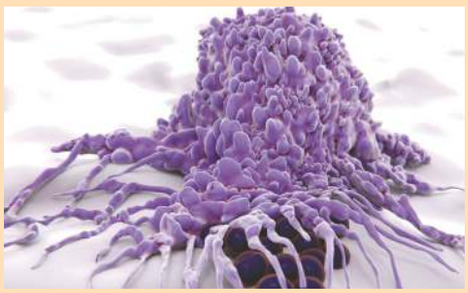
The first time the immune system meets a new infection it takes up to a week for the specialised immune cells to appear. In this time the pathogen can multiply and people can become very sick. Vaccinations bypass this step by giving the immune system an opportunity to train beforehand.

The first vaccine was developed by Edward Jenner in 1796. He noticed that milkmaids didn't catch smallpox; they were exposed to a similar disease, cowpox, and their immune systems were better trained. Jenner tried infecting children with cowpox and found that they too gained protection against smallpox.

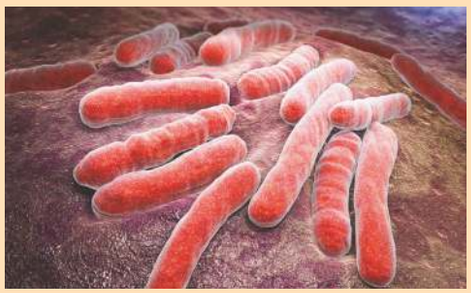
Vaccinations have been developed against dozens of infectious diseases since, and they are now being made to teach the immune system to fight other illnesses, too.

Training the immune system

Vaccinations are like a training programme for your immune system, giving it a sneak peek at enemies that it might encounter in the future so that it can prepare in advance. They can be made in different ways but usually contain inactive bacteria or viruses, or examples of molecules that the pathogens make.



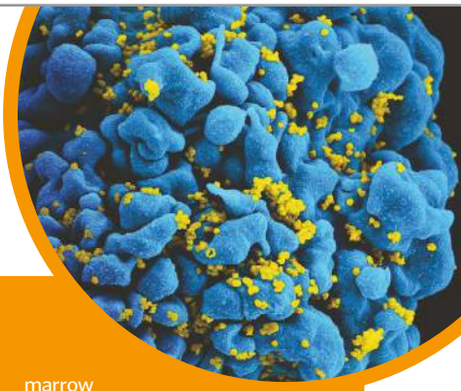
When the vaccination has been injected your immune system comes to have a look. It will examine the parts of the pathogen and work out the best way to attack, as though it were fighting the real thing. After the vaccine has been cleared up some of the cells that fought it remain in the body on patrol as 'memory cells'.



When you encounter the real pathogen, your immune system will be ready to respond. Instead of spending time working out what to do, the memory cells left over from the vaccine instantly clone themselves, producing an army of cells that can clear the infection before you get sick.

The end of HIV

How do you hunt down a virus that's hiding in your own immune system?



37 million

In 2015, nearly 37 million people were living with HIV

Over half of people with HIV can't access treatment

1.1 million

people die as a result of AIDS each year

HIV is transmitted through body fluids, including blood, semen and breast milk

8 out of **10** pregnant women with HIV receive treatment to minimise the risk to their child

HIV infects the immune system, crippling the body's defences

40%

of people with HIV don't know they're infected

Antiretroviral therapy stops the virus replicating

Condoms, HIV testing and circumcision help to reduce transmission

HIV puts people at risk of catching other diseases like tuberculosis

Human Immunodeficiency Virus (HIV) hijacks the immune system. The virus gets inside, inserts its genetic code into the genome of a cell and transforms it into a factory to make more of the virus. While this is happening the cell is unable to function normally and gradually, as more and more cells are taken over, the immune system is left seriously weakened. The result is known as Acquired Immune Deficiency Syndrome (AIDS).

HIV is now treatable with a combination therapy that stops the virus from replicating. The amount of virus often dips so low in the blood that the disease can't be passed on. Transmission from mother to child is also being eliminated with new drugs. However, not everyone has access to treatment.

The gold standard for the future of HIV medicine would be a vaccine that can teach the immune system to neutralise the virus with a coating of antibodies. In theory, this could be used not only to prevent infection but also to stop the disease coming back in people who have some of the virus still hiding in their systems.

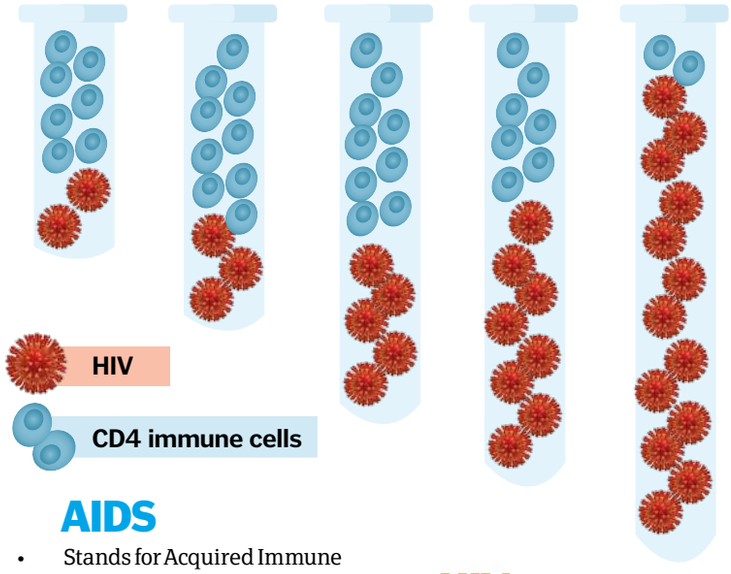
This is a huge challenge; the virus shape-shifts to avoid detection and the immune system doesn't usually respond. But new vaccines are being trialled all the time, and as our understanding of HIV and the immune system improves, we are inching closer to making it a reality.

How hard is it to cure?

HIV stitches its own genome into the genome of a particular type of immune cell (white blood cells known as CD4) so that the two are permanently linked together. Antiretroviral treatment can stop the virus from making copies of itself, but they can't get rid of it completely unless the immune cells themselves are killed.

This has only ever been done once, in 2007. The Berlin Patient had cancer and needed a bone marrow transplant. His own immune system, carrying HIV, was destroyed and replaced with donor cells. They had a genetic mutation that made it harder for HIV to infect them, and the patient was cured of the virus.

Bone marrow transplants are risky, however, and there aren't enough donors available, so it's not a practical solution to rid the world of HIV altogether.



AIDS

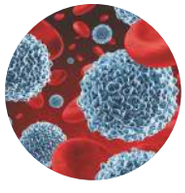
- Stands for Acquired Immune Deficiency Syndrome.
- Is the disease caused by HIV.
- Takes advantage of the damaged immune system that is unable to fight it.
- People die due to infection or resulting cancer.

HIV

- Stands for Human Immunodeficiency Virus.
- Is the virus that causes AIDS.
- Infects the immune system.
- Infection compromises the cells of the immune system.

Timeline

1981
Men in California start to fall ill with unusual infections after their immune systems become weakened.



1983
Scientists discover that Human Immunodeficiency Virus (HIV) is the cause of Acquired Immune Deficiency Syndrome (AIDS).

1985
Commercial blood tests for HIV are invented, allowing screening to begin.

1987
The first drug treatment for HIV, azidothymidine, is approved.

1996
Triple-drug therapy is introduced, turning HIV infection into a long-term disease.

2007
A single patient in Berlin is cured by a pioneering bone marrow transplant.

Future
A drug is developed to reveal HIV lurking in dormant cells.

Future
A vaccine is developed to train the immune system to attack HIV.

Can cancer be cured?

Huge progress has been made over the past century, but what happens next?

Cancer is an ancient disease; tumours have been found in Egyptian mummies and even in the fossils of dinosaurs. It happens when genes involved in growth and repair go wrong. Affected cells make copy upon copy of themselves, and these new cells start to break away, travelling around the body and making yet more copies elsewhere.

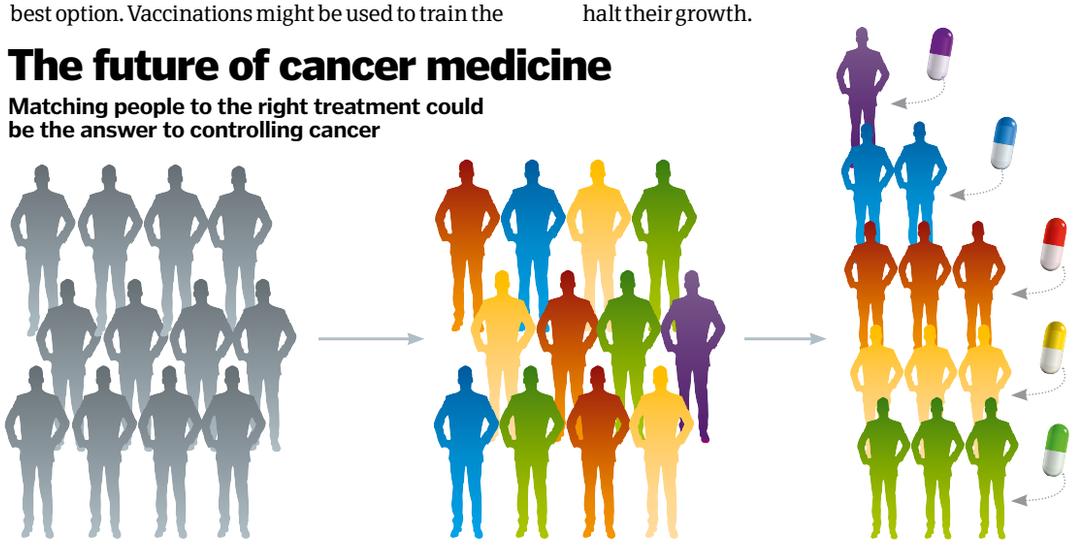
If cancer is caught early, it can already be cured. If the tumour is removed, the cancer is gone. However, once the cancer has spread it is harder to treat, and the more it spreads, the less likely people are to survive.

Stopping cancer before it really starts would be the best option. Vaccinations might be used to train the immune system to recognise cancer cells, or a routine blood or breath test could be developed to pick up the earliest signs of the disease. However, the likelihood of cancer increases with age, and with people living longer, the incidences are rising.

For those who do develop the disease, several futuristic treatment options are already being developed. Future humans could end up having their immune systems retrained and augmented, or they might receive genetically engineered viruses designed specifically to infect and kill the tumour. We might even be able to switch genes on and off inside tumour cells to halt their growth.

The future of cancer medicine

Matching people to the right treatment could be the answer to controlling cancer



Group of patients
Several people might have brain cancer, but not all brain cancers are the same.

Genetic testing
The patients are tested to find out the exact genetic and chemical makeup of their tumour.

Treatment matching
Patients are matched with treatments that specifically target the weaknesses of their own cancer.

Where is the cancer cure?

Cancer gets a lot of research money, and thousands upon thousands of scientists are working to try and find the cure, so where is it? If you can cut the tumour out before it has a chance to spread, you can cure it, but if any cells have escaped they need to be found. Radiotherapy and chemotherapy can help to mop up stragglers, but they don't always work, and some cancer cells develop ways to avoid them. The big challenge is that everyone is different, and so too are everyone's cancers. Tumours don't just differ between people, they also change over time. The challenge is to find out how they change and how these different weaknesses can be targeted with treatments.

Timeline

1846
The invention of general anaesthetic paves the way for surgery to finally remove tumours.

1880s
The first mastectomy is performed, providing a new treatment option for breast cancer.

1903
Radium is used to treat skin cancer in what is the first example of radiotherapy.

1949
The first chemotherapy drug is approved. It is nitrogen mustard, a WWII weapon.

1950s
Smoking is finally shown to cause lung cancer, encouraging millions to give up.

1990s
Cancer mortality starts to drop in developed countries as diagnoses and treatments improve.

Future
Personalised medicine becomes reality, with patients matched to treatments based on their genes.

Future
A simple blood test is developed to pick up the very earliest signs of cancer.

14 million
people are diagnosed with cancer each year

9 million
people die due to cancer each year

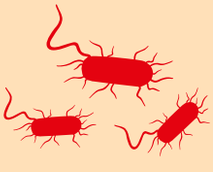
Lung cancer is the most deadly type of cancer for both genders

Breast cancer is the most common type of cancer in women

The older you are the more likely you are to get cancer

Cancer is not contagious but it can be genetic

Viral infections can cause some cancers



Lifestyle changes could prevent a third of cancers

The earlier cancer is detected, the easier it is to treat

Eliminating malaria

This deadly disease is carried by mosquitoes, but work is being done around the world to wipe it out

Just one mosquito bite is enough to kill you in some parts of the world. Inside the midgut of Anopheles mosquitoes, gametocytes from the plasmodium parasite mature and combine. These are the equivalent of human sperm and eggs, and the result is hundreds of newly formed parasites ready to infect their next victim.

The parasites migrate up to the mosquito's salivary glands and when it feeds again they enter the human bloodstream. They infect cells in the liver and begin to divide, before spreading back into the blood. As they continue to grow, the cells split open, releasing even more parasites and causing havoc for the body.

Malaria parasites can't reproduce without both mosquitoes and humans, giving us a tantalising opportunity to eliminate them. One idea is to genetically modify colonies of mosquitoes and release them to breed with their wild counterparts; this could be used to introduce damaging genetic traits into the population, either killing the parasites or killing the mosquitoes themselves. Another option is to develop fungi that can infect and kill the insects.

Other options for elimination include designing new insecticides to keep insect numbers down and developing a vaccine to halt transmission.

10-18
Days it takes for malaria parasites to reproduce inside a mosquito

Malaria was first written about in ancient China in 2,700 BCE

3.2 billion
people live in regions where they are at risk of catching malaria

400,000
people die of malaria each year

70%
of malaria deaths are children under the age of five

Malaria is caused by parasites that infect humans and mosquitoes

Spraying houses with insecticide is the best way to stop transmission

Last year **95** countries reported cases of malaria

214 million
cases of malaria were reported in 2015

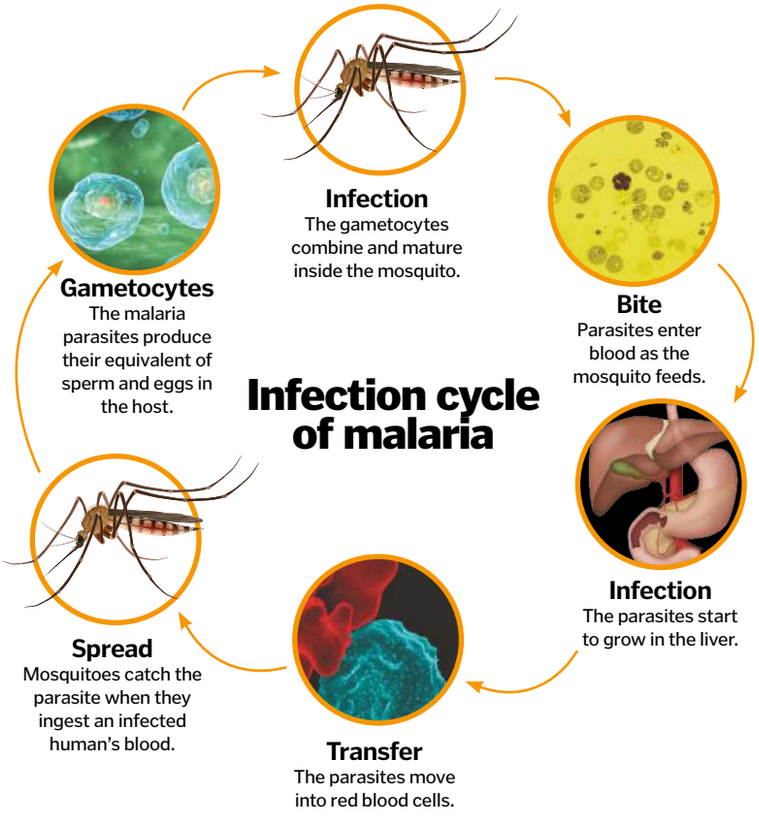
Global elimination is tough

The World Health Organization first initiated an attempt to rid the world of malaria in 1955. The idea was to use a combined attack, spraying houses to get rid of the mosquitoes and using antimalarials to kill the parasites. They had some successes in areas where the climate was moderate and mosquitoes thrive only during certain seasons, but in other places the program didn't work as well.

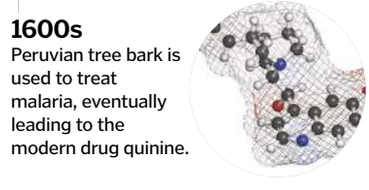
Mosquitoes started to become resistant to pesticides and the parasites resistant to treatments. This, combined with wars, political unrest and patchy access to resources, meant that coordinating an effective global attack against malaria became an impossible goal.

In 2015, the WHO reissued their challenge. But today we are facing even stronger versions of the parasite and vector, and new weapons are needed to eliminate them.

Infection cycle of malaria



Timeline



1600s
Peruvian tree bark is used to treat malaria, eventually leading to the modern drug quinine.

1880
The parasite that causes malaria is discovered in blood samples taken from patients.

1897
It's discovered that mosquitoes are able to transmit malaria from one person to another.

1939
The DDT pesticide is invented, allowing people to control numbers of malaria-carrying mosquitoes.

1951
Malaria is wiped out in the US after a government eradication programme sprays millions of homes.

2015
The World Health Organization endorses a new strategy to eliminate malaria for good.

Future
Malaria-carrying mosquitoes are wiped out by genetically modified insect mates.

Future
World declared malaria-free thanks to the eradication campaign.

Halting heart attacks and strokes

Diseases of the heart and blood vessels are the world's biggest killers

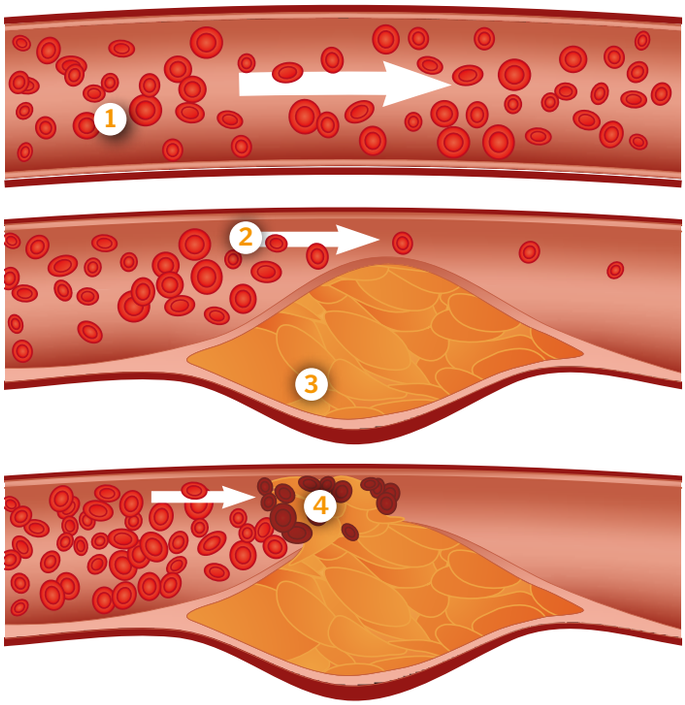
When arteries and veins become clogged with fat, rough plaques form and narrow the tubes. As the blood tries to force its way through it swirls and twists and more damage is done. The fatal blow comes when parts of the blockage break away. Clotting molecules in the blood interpret the roughness as a cut that needs to be sealed. They start to build a clot, and as the circulating blob gets larger, it eventually becomes lodged in the tubes, cutting off the blood supply.

The damage can't always be repaired, but the latest research could change that for the future. Stem cells are cells that haven't yet decided which part of the body to become. With some coaxing in the lab, they can be converted into new blood cells, new skin cells, or even new heart muscle. Harvard scientists have already made a life-size beating heart by convincing stem cells to become heart muscle and growing them on a scaffold. In the future, custom organ replacements could be made artificially on demand.

If this doesn't work, another option is gene therapy, which is already being trialled for heart failure. Genes are delivered to the cells, telling them to make different molecules and potentially allowing the body to be reprogrammed from the inside out.

How heart disease starts

The slow accumulation of fat can lead to a deadly blood clot



1 Normal vessel
Healthy blood vessels have smooth internal walls, allowing the blood to slip easily around the body.

2 Disruption
When a blockage appears in the vessel, the blood quickly becomes backed up.

3 Plaque
Fatty deposits in the wall of the blood vessel cause it to bulge, narrowing the tube.

4 Clotting
A clot starts to form on the roughened surface, and the blood vessel becomes clogged.

Why haven't we cured it?

Cardiovascular disease is difficult to treat once a catastrophic event has happened; strokes and heart attacks deprive vital organs of oxygen, causing the affected tissue quickly dies. If you have a heart attack outside of a hospital, you have just a one in ten chance of surviving, and quarter of people who suffer a stroke will die within a year.

In order to meaningfully improve treatment of cardiovascular disease we need to be able to repair or replace damaged tissues, or we need to prevent it happening in the first place. Neither one is easy to do.

Timeline

1899
Pharmaceutical company Bayer begin manufacturing a new drug called aspirin in Germany.

1930
The defibrillator is invented, allowing stopped hearts to be restarted with electricity.

1958
The first implantable pacemaker is installed, allowing the heart to be controlled.

1960
The first heart bypass surgery is performed to divert blood around damaged vessels.

1967
The first human heart transplant is performed, allowing damaged organs to be replaced.

1987
The first cholesterol-lowering statin drug hits the market, helping to prevent heart attacks.

Future
Gene therapy is used to reverse the damage done by heart attacks.

Future
Custom-grown replacement hearts are produced from people's own stem cells.

Cardiovascular disease killed

17.2 million

people in 2012

Heart attack symptoms include chest, arm and jaw pain, sweating and vomiting

Someone has a stroke every 2 seconds

There are over 2.5 million heart attack and stroke survivors in the UK

Men are more likely to die of heart disease than women

A third of adults in the UK have high cholesterol

The most important risk factors are smoking, diet, exercise and alcohol intake

Stroke symptoms include sudden weakness on one side of the body, confusion and slurred speech

Heart disease and stroke are the first and second most common causes of death

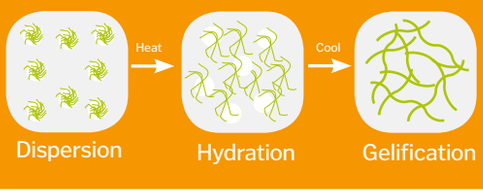
Creative culinary science

Feast your eyes on the delicious dishes created by the top chefs trained in molecular gastronomy

Foam can be used to present familiar flavours in an unfamiliar texture

Gels

When experimenting with textures, chefs are able to turn liquids into solids by adding a gelling agent called a hydrocolloid. Common hydrocolloids used in cooking include gelatine, agar-agar and sodium alginate and are made of tightly-wound coils of long protein or carbohydrate molecules. When added to liquid, the molecules evenly disperse and then heat is applied to cause them to hydrate and unfurl. As the mixture cools back down again the long strands form a crosslinked network that traps the liquid molecules and forms a solid shape. The result is a firm gel or jelly packed full of the flavour of the original liquid.



Liquid nitrogen

To introduce some drama to their food presentation, chefs can garnish their drinks and dishes with a dash of liquid nitrogen to produce a magical smoke effect.

Nitrogen is normally a harmless, odourless and tasteless gas and is present in the air we breathe, but when cooled to below -196 degrees Celsius it becomes a liquid. If it is exposed to warmer temperatures again, it quickly boils and evaporates, condensing the moisture in the surrounding air to create a dense fog.

Liquid nitrogen isn't just useful for decoration, though, as it can also be used to make delicious frozen desserts. When making ice cream, the supercooled liquid will freeze the ingredients instantly. This prevents ice crystals from forming so that the finished product is incredibly smooth and creamy.

Nitrogen must be handled with care as a liquid but is harmless as a gas

Spherification

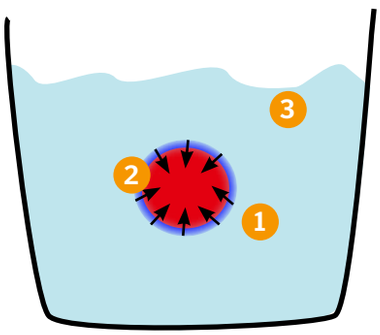
To add an explosion of flavour to a dish or cocktail, chefs can use clever chemistry to create spheres of flavoured liquid. The liquid is contained inside a thin gel membrane that when put under slight pressure in your mouth, bursts open to reveal the delicious contents within.

The spheres can be created using one of two spherification techniques. Basic spherification has the benefit of creating an extremely thin gel membrane that is almost imperceptible in your mouth, but this will not work if the liquid has a high acidity. The gel also keeps forming after the liquid is removed from the bath, so the sphere must be served immediately, before it becomes a solid gel ball.

Reverse spherification is best used for liquids with a high calcium or alcohol content, and although it creates a thicker membrane, the finished sphere is longer lasting as the gel stops forming as soon as it is removed from the bath.

Spherification can be used to create small, caviar-like balls or large domes

Basic spherification

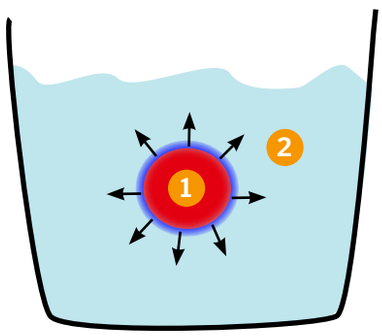


1. Sodium alginate solution
Sodium alginate is dissolved in the flavoured liquid and dropped into a bath of calcium lactate.

2. Gel coating
The calcium ions diffuse towards the centre of the droplet even after it is removed from the calcium bath.

3. Calcium lactate bath
Calcium ions displace the sodium from the alginate molecules and hold them together to form a gel.

Reverse spherification



1. Calcium lactate solution
Flavoured liquid is infused with calcium lactate and then dropped into a bath of sodium alginate.

2. Sodium alginate bath
Calcium ions diffuse from the droplet into the alginate, forming an outer gel layer until it is removed from the bath.

Sous vide

To ensure their food is cooked to perfection, many top chefs use a method called sous vide, which is French for 'under vacuum'. It involves sealing raw ingredients in vacuumed pouches and then placing them in a water bath heated to a precise temperature. This cooks the food evenly from edge to edge, maintaining moisture and tenderness in the centre while preventing the outsides from being overdone.

Despite the name, vacuum sealing isn't actually vital for sous vide, as temperature control is more important. However, it does have certain benefits. Sealing the food allows for more efficient heat transfer from the water and retains moisture and flavour during cooking. It also inhibits off-flavours that can occur when food is exposed to oxygen in the air. It's a process thought to date back to 1799.

Sous vide can make thick cuts of meat tender yet still medium-rare all the way through

"Nitrogen becomes a liquid when cooled below -196 degrees Celsius"

1. Efficient cooking
Water transfers heat more efficiently than air, so food can be cooked at lower temperatures.

2. Succulent flavour
Cooking at low temperatures means the cell walls in food do not burst, providing a higher level of succulence.

3. Perfect 'doneness'
Precise temperature control ensures proteins, such as fish, chicken and eggs, are cooked to perfection.

4. Safe to eat
Cooking at exact temperatures and times ensures the food is safe to eat and determines expected shelf life.

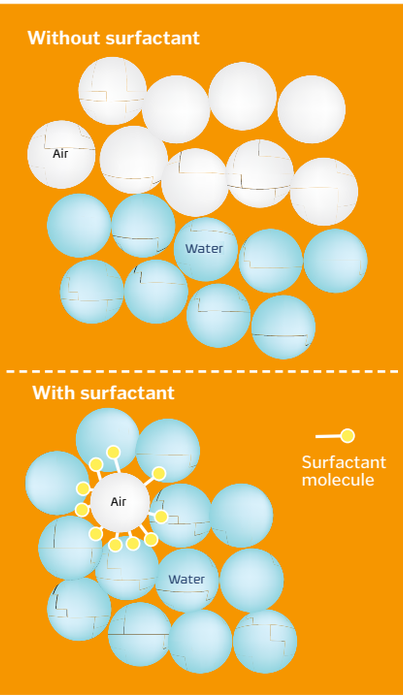
5. Ideal texture
When cooking vegetables, low temperatures ensure they are cooked thoroughly but maintain a crisp texture.

Foams

Thanks to science, chefs are able to present flavours in all sorts of interesting textures, including that of foam. To create an edible foam garnish, a surfactant such as egg white, gelatine, lecithin from egg yolk or agar-agar from seaweed is added to a flavoured liquid, and then air bubbles are introduced by shaking, blending or injecting nitrous oxide into the mixture.

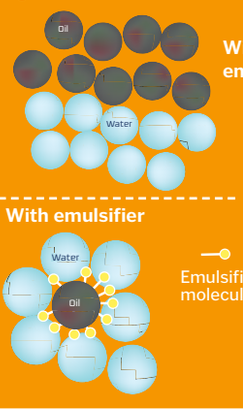
The surfactant contains both water-attracting regions that dissolve in the liquid and water-repelling regions, which stick to the air bubbles. This helps to reduce the surface tension of the air bubbles, stopping them from popping or escaping so that foam is formed.

Foam physics takes advantage of a molecule's polar or non-polar properties



Emulsions

Oil and water don't naturally mix, so when a chef wants to create a deliciously creamy sauce in the flavour of their choice, they need the help of a special ingredient. Surfactants, such as egg whites and lecithin from egg yolks, enable the two liquids to mix in the same way they help keep the air bubbles inside edible foam. One part of the surfactant is attracted to the water, while the other is attracted to the oil, so it is able to bind the two together to form an emulsion.



60 SECOND SCIENCE

Genetically modified organisms

HOW AND WHY DO SCIENTISTS MANIPULATE GENETIC INFORMATION?

BACKGROUND

Organisms have tens of thousands of proteins, and genetic modification is the process of them being transferred from one organism to another. Nature has done this for millennia. For example, some types of sweet potato express a gene from bacteria that introduced itself into the potato genome. Scientists then developed a way to do this intentionally.

The first patent for a genetically engineered organism was a bacterium. Developed in 1971 by Ananda Chakrabarty, an Indian-American biologist, it was designed to have a taste for crude oil so that it could be used to help clear oil spills by either absorbing the oil or breaking it up.

IN BRIEF

Scientists decide what trait they would like to introduce into an organism, such as resistance to drought or the ability to produce a vitamin. By analysing the genetic code they can identify exactly which part of the DNA codes for the gene of interest and select enzymes that will cut out the part they need. Generally, they will then alter the genome of a plant by using a bacterium called *Agrobacterium tumefaciens*. This bacterium naturally enters plants' cells in the wild.

A few specific genes are then removed from the bacterial plasmid, a circular genetic structure that can replicate independently and be transmitted across bacteria. This cutting leaves a linear piece of DNA that codes just for replication instructions and for basic cell functioning. To create the new 'recombinant plasmid' the cut gene of interest, the linear receiving DNA and the enzyme DNA ligase are all mixed together, causing the integration of the new gene.

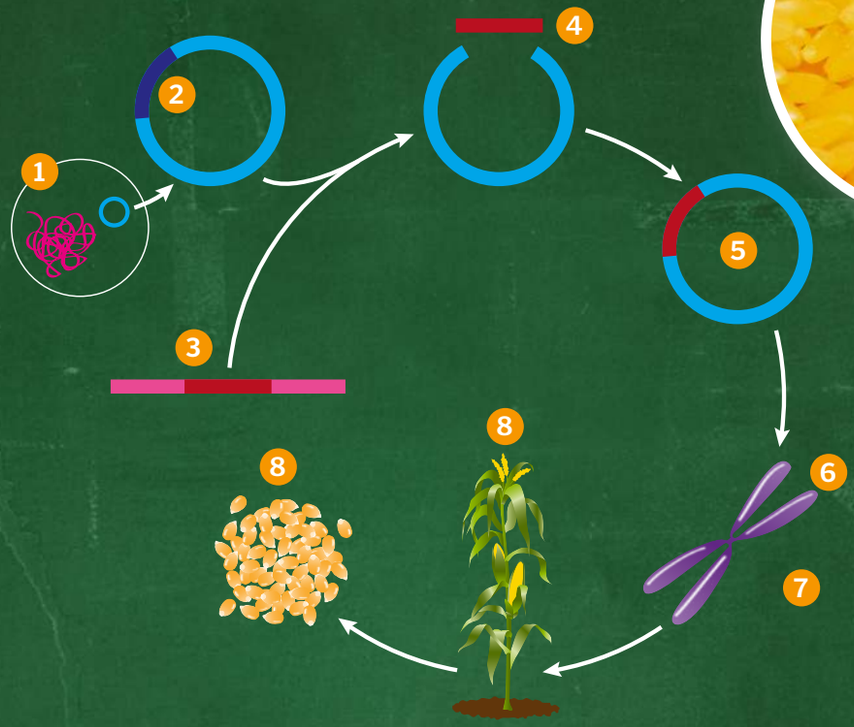
The cells are grown in culture and will produce seeds as adults, which will all inherit the transgene, though they may not express it.

SUMMARY

GMOs are created using gene manipulation technology. By facilitating the uptake of a foreign gene into a new host, scientists can produce an organism that expresses a trait it wouldn't usually have in nature.

Making a GMO

How scientists use genetic engineering to give plants new characteristics



1. First, the plasmid is removed by opening up the bacterial cell and purifying the contents inside.

2. T-DNA is cut from the plasmid using restriction enzymes, which slice the genome at specific points to remove some genes.

3. The foreign DNA that needs to be transferred into the T-DNA is also cut using restriction enzymes to select the target gene.

4. The cutting process creates a linear molecule that is ready to accept new DNA.

5. The gene and opened vector are mixed together with DNA ligase, an enzyme that connects the ends of the gene and open vector.

6. Heating up the cells (heatshocking) is thought to create pores that allow the engineered plasmid to enter the plant cell.

7. The bacterium carries the gene of interest and the replication instructions into the chromosomes of a plant cell wall.

8. The plant cells grow in culture and eventually produce seeds that contain the naturally inherited transgene.

GMOS MATTER

GMOS HAVE THE POTENTIAL TO REDUCE WORLD HUNGER AND MALNOURISHMENT, PARTICULARLY FOR THOSE LIVING IN LOW-INCOME COUNTRIES. EXAMPLES OF SUCH INNOVATIONS INCLUDE 'GOLDEN RICE', WHICH IS BEING MODIFIED TO HAVE AN ENHANCED LEVEL OF THE MUCH-NEEDED VITAMIN BETA-CAROTENE.

OTHER TYPES OF RICE HAVE BEEN MODIFIED SO THAT THEY CAN SURVIVE WITH VERY LIMITED WATER AFTER HAVING A GENE FROM A DESERT PLANT INTRODUCED INTO ITS GENOME. TOMATOES THAT ARE RESISTANT TO FROST AND FREEZING TEMPERATURES HAVE ALSO BEEN MADE USING AN ANTI-FREEZE GENE FROM A COLD-WATER FISH.

IN THE FUTURE, WE COULD EVEN SEE THE INTRODUCTION OF VACCINES AND MEDICINE IN SOME FOOD, LIKE THE POTATO THAT HAS BEEN ENGINEERED TO PRODUCE AN EDIBLE VACCINE AGAINST PATHOGENIC E COLI.

How does soap clean?

Find out how interactions between molecules help get our hands clean

Soap is an ancient concept that can be traced back to 2,800 BCE in Babylon, and the basic principle of mixing animal or vegetable fat with an acid has remained the same from the very beginning. The chemical reaction that occurs when these are mixed is called saponification.

Soap doesn't actually kill any organism living on your hands, but it is so effective at removing the microbes that it doesn't need to. It's action comes from the way the soap molecules interact with the dirt on your skin. Water alone doesn't do much to help clean because water and fat don't mix and will separate instead. This is because dirt is filled with lipophillic (attracted to fats) molecules that are drawn to fat and repel water. This means the water is unable to attach itself to the dirt properly and wash it away.

A soap molecule gets around this because it has two ends. One end is hydrophilic (attracted to water) and the other is lipophillic. The lipophilic end attaches itself to the fat on your hands and the hydrophilic end surrounds the fat in a water layer that prevents it from repelling surrounding water molecules.

Both ends of the molecule are satisfied when the drops of oil are suspended inside a layer of water molecules. As you scrub your hands together when you rinse, the drops of water holding the fat are easily washed away.

Washing hands with soap in cold water is just as effective as with hot

The molecular mechanisms of soap

Five facts about dust

When it settles, the truth about dust is pretty fascinating

Space dust falls onto Earth

Some studies suggest up to 100 metric tons of cosmic dust falls on our planet every day! This dust originated in outer space and contains complex organic matter that could have been created by stars.

It helps produce beautiful sunrises and sunsets

Lower levels scatter a mix of wavelengths, giving a yellow colour, while a high amount scatters long, red light wavelengths more efficiently.

House mites live in your dust

Tiny arachnids called dust mites are living off your old skin cells. They have powerful enzymes to digest the tough cells, which are then excreted and will irritate our lungs. This is what causes dust allergies.

It's not 70% dead skin cells

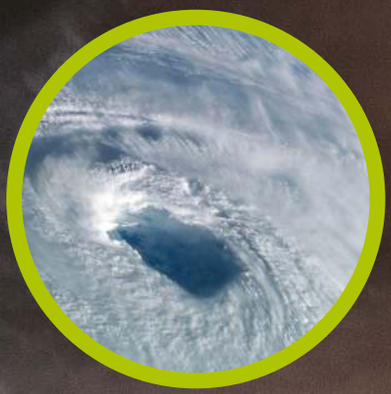
It's mostly made from animal dander, sand, space debris, pollen, fibers from texiles, and paper.

The world's largest source of dust is the Sahara desert

182 million tons of dust is blown away from the huge desert every year. Up to 27 million tons of this is deposited on the Amazon!

RECORD-BREAKING WEATHER

Discover where and when the elements have been at their most extreme



"Within 30 minutes the El Reno tornado was moving at 80 kilometres per hour"

The El Reno tornado produced a massive funnel cloud and several subvortices

Widest tornado

The classic tornado is funnel-shaped with a narrow bottom, but this isn't always the form these storms take, as the residents of El Reno, Oklahoma, found out on 31 May, 2013.

At around 6pm local time, the El Reno tornado formed at an intersection about 15 kilometres southwest of the city. It soon began moving towards the town and rapidly increased in speed and size. Within 30 minutes it was moving at 80 kilometres per hour and had ballooned into a massive maelstrom of thunder and wind 4.2 kilometres across. Luckily for El Reno's 18,500 residents, it largely missed the city as it tore across 16 kilometres of farmland, ripping up crops and flattening farm buildings before dissipating at about 6:45pm. Sadly, three American storm chasers weren't so lucky: they were among eight people killed by terrifying winds that reached speeds of up to 340 kilometres per hour.

Inside a mega twister

Get a closer look at how the El Reno tornado formed

Wind shear
A cold front from the north confronts a warm front from the south, creating a horizontal tube of rotating air.

Birth of a storm
Warm air near the ground surface rises, causing some of the rotating air to shift towards an upright orientation.

Mesocyclone
The vortex forms a mesocyclone: a rotating mass of air above the ground that is at least several metres across.

Supercell
The rotating updraft and thunderstorms within the cloud mass comprise a supercell.

In a spin
A vortex develops from the upended revolving air flows as they rapidly increase in speed and are accompanied by thunderstorms.

Subvortices
Mini tornados spin out from the main vortex unpredictably, causing three storm chasers to lose their lives.

Air movement
Warm air is pulled up through the mesocyclone while cool air creates a downdraft.

Most rainfall

Imagine having to mop up after getting almost two metres of rain in one day. That's what the citizens of the Cilaos, Reunion, had to do on 16 March, 1952 after an astonishing 1,870 millimetres of rain was believed to have fallen on the Indian Ocean island in just 24 hours. Yet that was just a shower compared with the 9,300 millimetres that was dumped on the residents of Cherrapunji, Meghalaya, India, throughout July 1861. Moreover, that came at the end of a 12-month period in which 26,461 millimetres poured on the town. Rain storms of this magnitude can occur in areas of mountainous terrain when moisture-laden air moves from a zone of high atmospheric pressure over the ocean to a region of low pressure over land.

Cherrapunji might be an unexpected tourist destination given its claim to fame

WR

LARGEST RAINDROPS

8.6 millimetres
September 1995, Brazil; July 1999, Marshall Islands

Heaviest snowfall

Snow can be fun in moderate quantities, but more than enough fell on Mt Shasta Ski Bowl, California, in early 1959 to build an entire army of snowmen. Between 13 and 19 February, 4.8 metres settled on the resort, a record amount for a single snowstorm in Northern America.

However, the title of 'snowiest place on Earth' is claimed by Paradise in Mount Rainier National Park, Washington. On average, over 16.3 metres of snow blanketed the park every year between 1920 and 2011, with over 31 metres settling in the period from February 1971 to February 1972 alone.

Snow falls when moisture in the air precipitates under sub-zero temperatures, forming tiny snow flakes that clump together and fall as snow. The heaviest snowfalls occur when air has passed over large bodies of water and an unstable atmosphere forces it to rise more quickly than usual.

Snowy conditions at Paradise, Mount Rainier, are the result of airflows from the Pacific Ocean

WR

-89.2 DEGREES CELSIUS

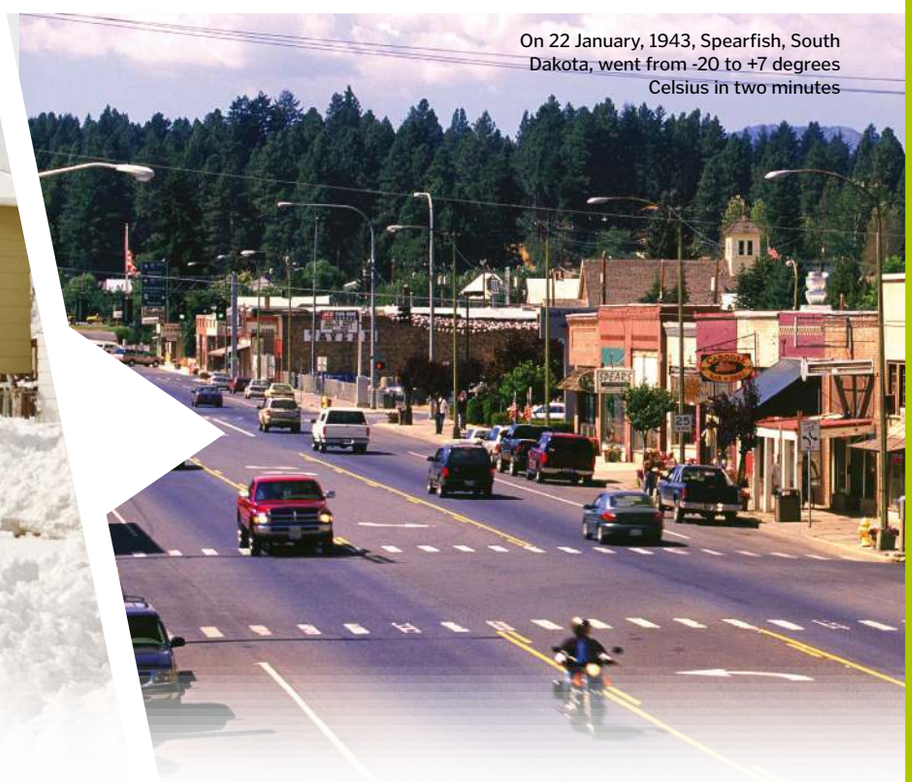
Coldest directly recorded temperature: Vostok, Antarctica, 21 July, 1983

The mining town of Marble Bar guarantees a warm welcome but bring plenty of water

WR
HOTTEST RECORDED TEMPERATURE
Death Valley, US
10 July, 1913

Longest heatwave

WR Meteorologists define heatwaves as periods when the temperature is above average for several consecutive days and nights. Such conditions are usually associated with high atmospheric pressure that compresses air near the surface, stifling circulation and preventing the formation of clouds that would otherwise help block out some sunlight. Unsurprisingly, record-setting heatwaves tend to occur in desert regions. The hottest air temperature ever measured on Earth is 56.7 degrees Celsius. It was recorded at Greenland Ranch, Death Valley, California, on 10 July, 1913. Luckily for the local wildlife, though, that heatwave lasted less than a week. At around 37 degrees Celsius, the temperature in the world's longest ever heatwave was balmy by comparison. Yet, that was small consolation to the residents of Marble Bar in central Australia who got no relief from the hot sun for 160 consecutive days from October 1923 to April 1924.



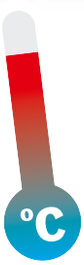
On 22 January, 1943, Spearfish, South Dakota, went from -20 to +7 degrees Celsius in two minutes

Most dramatic temperature change

WR We say that people "change like the weather" if they display sudden mood swings and it's an apt expression because the weather can be capricious.

The biggest temperature drop recorded in one day happened between 23 and 24 January, 1916 in Browning, Montana, when an influx of cold air sent the thermometer plunging from +7 to -49 degrees Celsius. The biggest swing recorded over a 24-hour period, though, happened in the town of Loma, also in Montana, between 14 and 15 January, 1972. The first morning was a frigid -48 degrees Celsius, but the next was a comparably pleasant +9 degrees.

Native Americans have a term that describes the winds that can create these conditions: 'chinook' or 'snow eater'. Coming inland from the ocean and flowing over the side of a mountain range, these winds replace cold Arctic air with warm, dry air.



"In one day, temperatures plummeted from +7 to -49°C"

Top tempests

The super storms that left behind a trail of destruction

Biggest ever typhoon

Super Typhoon Tip developed out of a tropical storm over the western Pacific Ocean in early October 1979. Over the next three weeks it whipped up the sea and land between Micronesia and Japan with wind speeds that reached 306 kilometres per hour over a diameter that stretched to 2,220 kilometres.

Strongest cyclone

With wind speeds of over 300 kilometres per hour, Typhoon Tip is the most intense tropical cyclone on record. It formed in October 1979 over the western Pacific, and its central pressure dropped to a record low, just 870 millibars at sea level.

Longest-lasting tropical storm

Although its name is not among the most exotic in storm history, the 1994 version of Hurricane (and sometimes Typhoon) John holds the world record for not letting up. For 30 days between August and September it marched relentlessly across more than 13,000 kilometres of the north Pacific.

Most tornadoes spawned by a hurricane

Hurricane Ivan developed into a Category 5 storm over the Caribbean Sea in September 2004. As it travelled across the southern US it spawned 119 tornadoes in just three days.

Deadliest cyclone

While its top wind speeds were well below those of the most powerful tornados, the Bhola Cyclone of November 1970 caused far more fatalities than any temperate zone twister. As it passed over parts of India and east Pakistan (now Bangladesh) it may have killed as many as 500,000 people.

"Hurricane John marched relentlessly for 30 days"

Tropical storms

See how hurricanes, cyclones and typhoons form monstrous masses of wind and water

Hurricanes produce devastating flooding as well as damaging high winds

Tropical cyclone
A cyclone is officially named if winds hit 119kph. By this point the cyclone's diameter can exceed 100km.

outflow cloud sh

spiral rainbands (thunderstorms)

408 KM PER HOUR
Fastest gust of wind: Barrow Island, Australia, 10 April, 1996

top view

Spiral pattern
The cyclone's spiral arms are bands of storms caused by air flowing outwards at the top under high pressure.

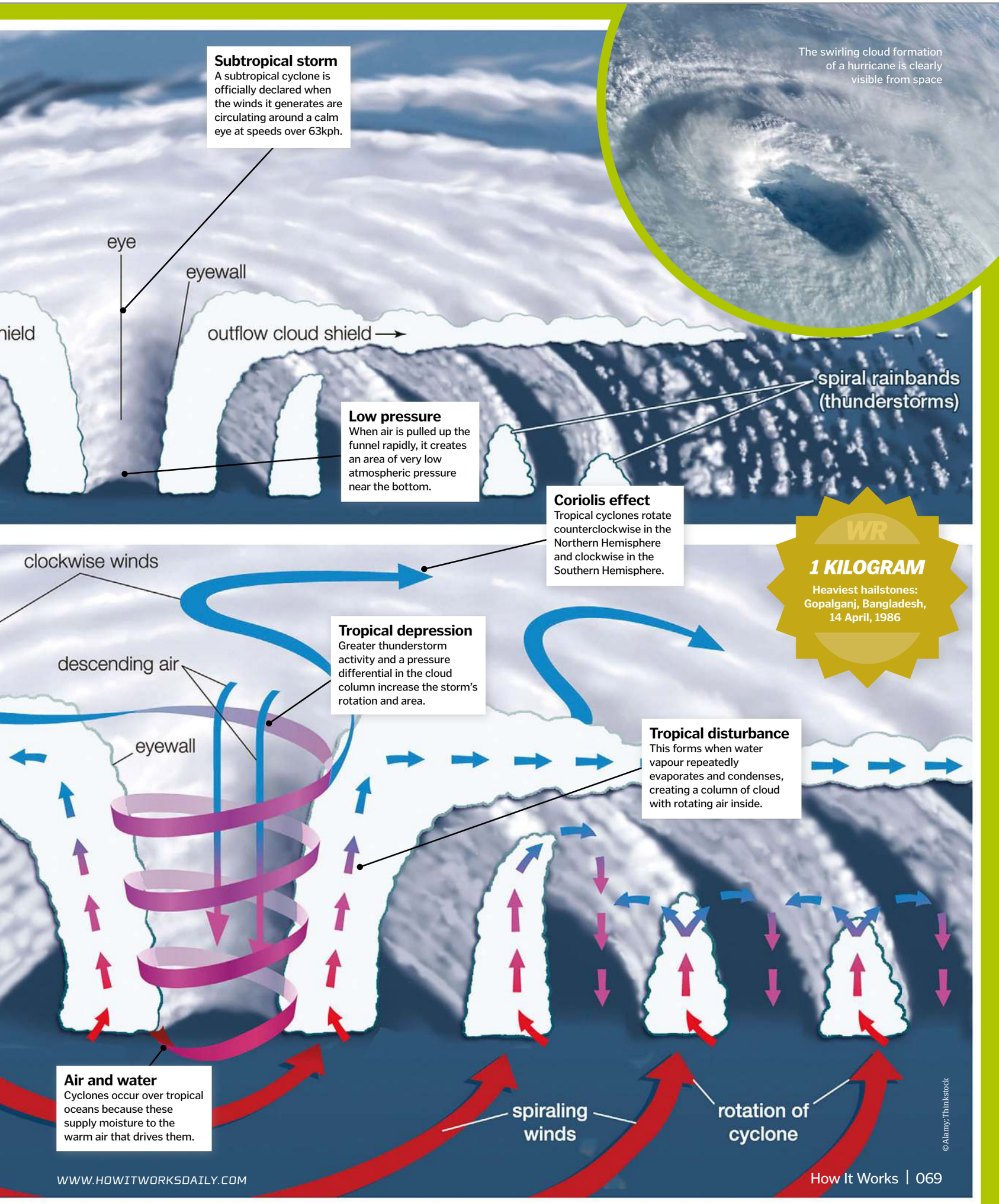
eye

eyewall

Areas often affected by hurricanes may have safe sites where residents can find shelter

0 miles 50 100 150 200

0 km 100 200 300



The swirling cloud formation of a hurricane is clearly visible from space

WR

1 KILOGRAM

Heaviest hailstones: Gopalganj, Bangladesh, 14 April, 1986

Life in Death Valley

What's behind this desert's springtime 'super bloom' floral phenomenon?

Deep within the Mojave Desert sits one of the hottest environments on our planet. The hostile Death Valley is over 13,500 square kilometres of sunken bedrock at 86 metres below sea level. With the scorched earth and golden sand dunes walled in by mountain ranges, the heat is trapped within the basin, causing the temperature to soar beyond a sweltering 46 degrees Celsius. The average rainfall over one year is just five centimetres, though some years there is no rain at all.

In this extreme climate it seems impossible that any life could survive. Yet just under the surface of the soil there are millions of heat- and drought-resistant seeds that wait for years, sometimes decades, for the perfect conditions to spring into life.

Very rarely, for just a few weeks over summer, the barren, cracked dirt bursts into a kaleidoscopic floral display with fields of vibrant yellow desert sunflowers and rich orange Californian poppies. This natural wonder is set in motion first by rainfall over winter, which erodes the protective wax or protein layer encapsulating the seed. They need desert showers to continue in bursts of around half an inch over the remainder of winter, but without their protective layer, any extreme temperature or too much water (or not enough) will kill them before they have a chance to sprout from the ground and bloom.

This 'super bloom' phenomena extends far beyond the usual spring bloom and is key to the desert flowers' secret to survival in the hostile desert. Rather than struggle year-round, they bloom at just the right time to complete a swift reproductive cycle, having first waited for enough rainfall to support them.

This beautiful mass blooming attracts vast amounts of pollinators to Death Valley, including hummingbirds and butterflies, starting the cycle all over again.

Dehydrated soil cracks in Death Valley as summer temperatures rise to over 46°C

Other desert survivors...

Kangaroo rat
Dipodomys deserti

A kangaroo rat can survive its entire life without drinking a single drop of water! They have evolved to metabolize water from the starch and fat in the seeds they eat. They also shelter from the day's intense heat in underground burrows, surfacing mainly at night.

Devil's Hole pupfish
Cyprinodon diabolis

These tiny, heat-tolerant fish live only within a geothermal pool in Death Valley. Stuck in the same place since the last ice age (when the valley was home to a glacial lake) the Devil's Hole pupfish survive in the high salinity by drinking bountiful quantities of water and excreting the salt.

Desert tortoise
Gopherus agassizii

This ingenious herbivorous tortoise spends 90 per cent of its life hibernating and relies on its bladder to stay hydrated. The organ acts as a storage tank, and the tortoise reabsorbs the water back into its body. It can go an entire year without drinking any fresh water at all!

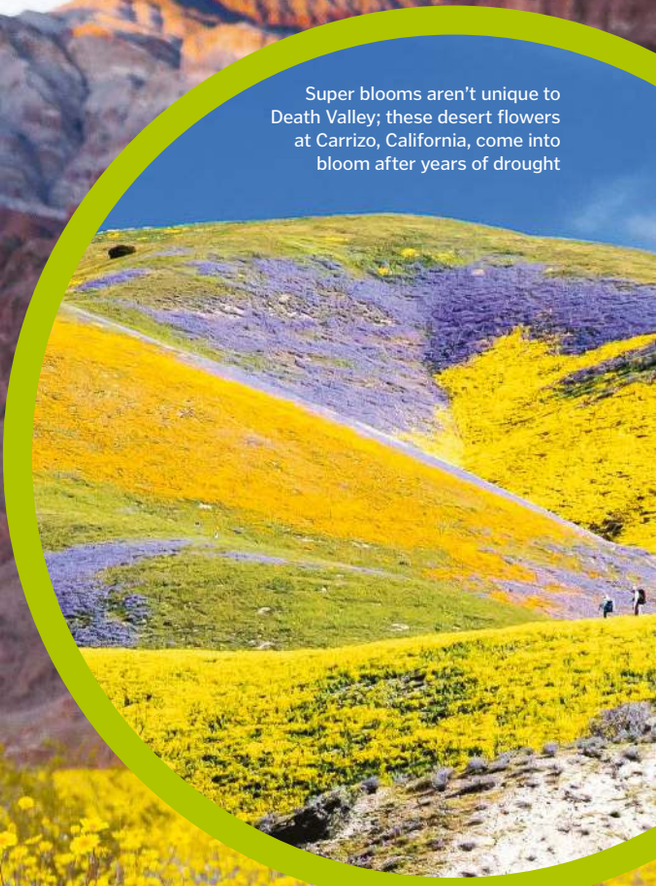
Creosote bush
Larrea tridentata

A medium-sized evergreen shrub, the creosote's small, waxy, pointed leaves conserve water by preventing moisture from being evaporated. It's known as the 'governess' in Mexico due to its ability to secure water by inhibiting the growth of surrounding plants.

Golden barrel cactus
Echinocactus grusonii

This cactus acts like a sponge. When there are periods of rainfall the plant expands to accommodate the newly available moisture and will survive on the stored water during dry spells while gradually shrinking to its original size.

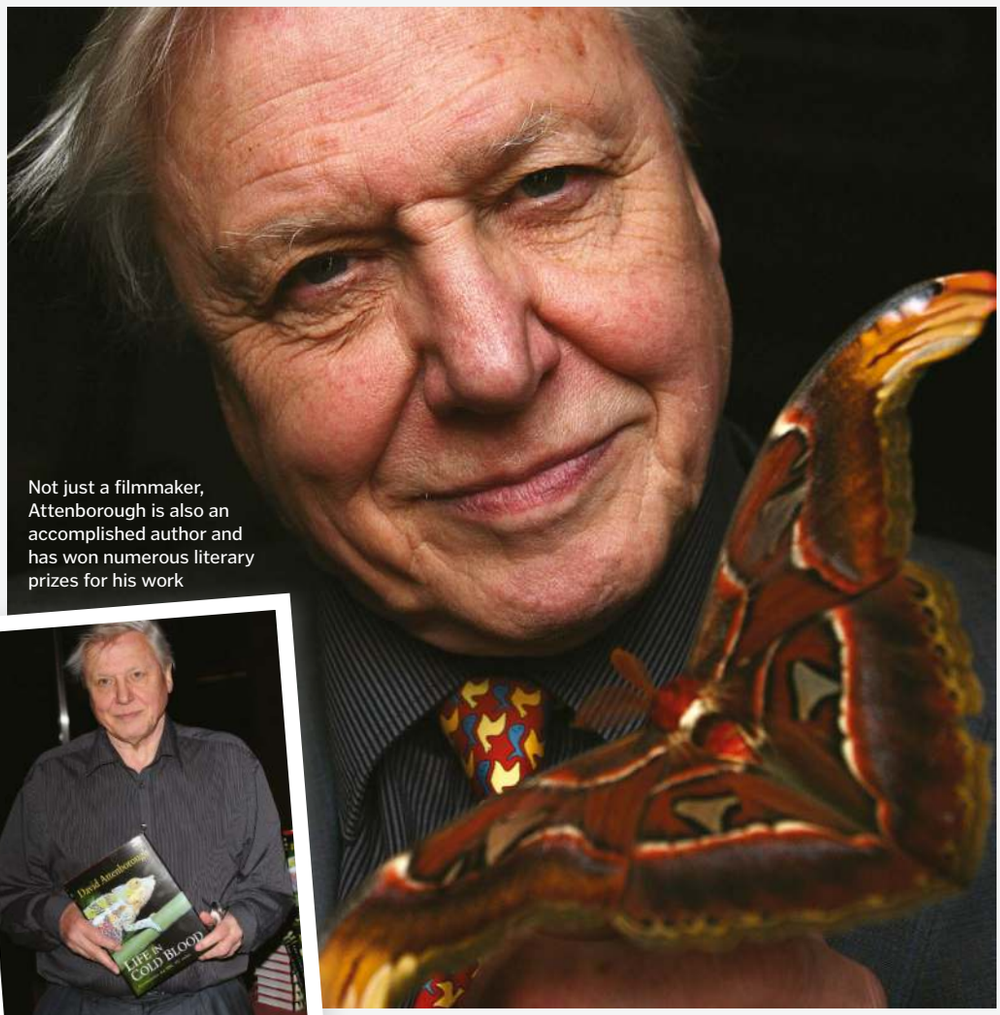
"Very rarely, for just a few weeks over summer, the cracked dirt bursts into a kaleidoscopic floral display"



Super blooms aren't unique to Death Valley; these desert flowers at Carrizo, California, come into bloom after years of drought

Sir David Attenborough

The godfather of broadcasting has had an incredible career so far, bringing the natural world to our living rooms for over seven decades



Not just a filmmaker, Attenborough is also an accomplished author and has won numerous literary prizes for his work

It really isn't a nature documentary if it's not accompanied by *those* dulcet tones is it? Sir David Attenborough is an undisputed national treasure for his pioneering work in film and the natural world.

Born in London the same year as the Queen and raised in Leicester, Sir David attended Clare College at the University of Cambridge to study natural sciences, graduating in 1947.

After a spell in the Royal Navy after university, Attenborough joined the BBC in 1952 as a trainee producer. *Zoo Quest* was Sir David's first animal-based programme, which launched in 1954. He wrote, presented and produced this landmark series that ran until 1963. In 1965 he was promoted to the role of controller for the new channel BBC2, where he oversaw the introduction of Europe's first all-colour television network, and in 1969 he assumed the title of BBC director of programmes. These roles involved the commissioning of all kinds of new content, and it was Sir David who brought still-beloved programmes such as *Match Of The Day*, live snooker and *Monty Python* to our screens.

The documentaries were to become Attenborough's great passion, and in 1973 he resigned from his position in favour of concentrating on producing these natural world features. Sir David never classed himself as an 'animal lover', he is just hugely fascinated by them. He has also admitted in the past that the only animals he dislikes are rats!

His first endeavour was called *Eastwards With Attenborough*. Production began in 1973, starting a tradition of excellence in filming the natural world. With a series of groundbreaking documentaries under his belt, such as *Life On Earth* (one of the BBC's most ambitious filming projects at the time) and *The Living Planet*, Sir David was knighted by the Queen in 1985 for services to factual broadcasting.

Throughout the 1990s and 2000s Sir David developed a huge wealth of programming that delved into topics such as animal behaviour and environmental issues, all the while striving to use the very latest in filming technology to bring

A life's work

The stellar career (so far) of Sir David Attenborough

1926
Born 8 May in Isleworth, London but grows up at University College, Leicester where his father Frederick is principle.

1947
Graduates from Clare College, Cambridge University with a degree in natural sciences.

1952
Joins the BBC as a trainee. Achieves first television credit for documentary entitled *Coelacanth*.

1955
The first episode of *Zoo Quest* (entitled *Zoo Quest To West Africa*) is aired. It is hugely popular with audiences.

1973
Resigns from position of director of programmes to focus on wildlife film making full-time.

THE BIG IDEA

Filming technology

Across his exceptional career, Sir David has always pioneered the advancements in wildlife filming. From his work introducing Europe's first colour television service in July 1967 to using time-lapse filming for the *Private Life Of Plants* (1995) to show incredible images of plant growth never before seen on TV, he has consistently led the way.

Among his many landmarks Sir David narrated the BBC's first nature series in both HD (*Planet Earth*) and 4K (*Life Story*), as well as the UK's first 3D documentary, *Flying Monsters 3D,* which aired on Sky 3D in 2010. In 2015 Sir David also launched **attenboroughsreef.com**, an interactive platform documenting the amazing life and perilous ecological situation of the Great Barrier Reef. While filming for this he also broke a record for the deepest submersible dive on the Reef at 305 metres.

Sir David is the only filmmaker to have received BAFTA awards for black and white, colour, HD and 3D television!

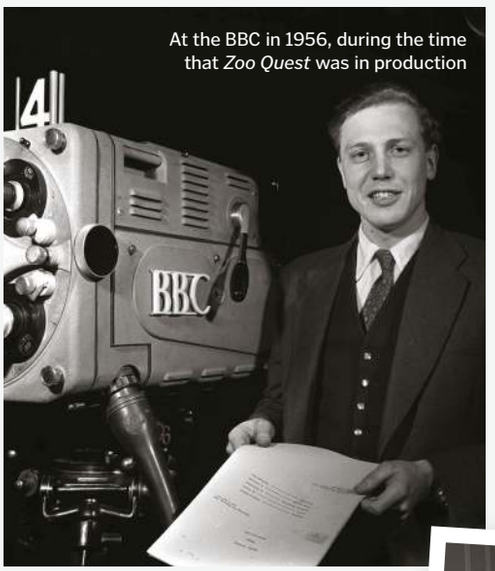
the wonders of the animal kingdom to television. Series such as *Planet Earth, Life In The Freezer, The Blue Planet* and *Life In Cold Blood* (to name just a few) helped to inspire millions across the country to learn more about the natural world.

With 32 honorary degrees – more than any other person – along with a fellowship to the Royal Society as well as many other academic institutions, Sir David Attenborough's life's work to date has entertained and educated in equal measure. His enthusiasm and appreciation for nature spills out of every sentence he narrates to his captivated audience.

Sir David taking a hands-on approach while filming *The Life Of Mammals* in South Africa

"With a series of groundbreaking documentaries under his belt, Sir David was knighted in 1985 for his services to factual broadcasting"

In 2005 Attenborough was awarded the Insignia of the Order of Merit, an award from the Queen recognising exceptional achievements in the advancement of arts, learning, literature and science



At the BBC in 1956, during the time that *Zoo Quest* was in production

5 THINGS TO KNOW ABOUT... SIR DAVID ATTENBOROUGH

1
Gorilla encounter
One of the most famous moments of Sir David's career is his close experience with mountain gorillas while filming *Life On Earth,* which ended up with baby gorillas climbing on him in 1978.

2
Talented family
Sir David's elder brother was Lord Richard Attenborough (1923-2014), an Oscar-winning actor and director who starred in films such as *Jurassic Park.*

3
Explorer
To film *Life Of Birds,* Attenborough travelled over 411,900 kilometres! He also visited the North Pole in 2010 at the age of 83 as part of filming for *Frozen Planet.*

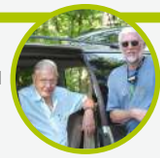
4
Big name
To honour Sir David there is a very varied group of species named after him, including fossils, beetles, moths and the long-beaked echidna, *Zaglossus attenboroughi.*

5
Unforeseen potential
In 1952, when Sir David accepted his first job at the BBC, he had only ever seen one TV programme! He was initially deemed undesirable as an 'on-air' talent due to his teeth.

1985
The Queen knights Sir David Attenborough for his services to factual broadcasting.

1990–2015
Produces a huge array of first-class wildlife and environmental documentaries, including two films entitled *The Truth About Climate Change* addressing the issues of global warming.

2016
Sir David celebrates his 90th birthday. Among many tributes in his honour, the NERC's newest polar research vessel is named the RRS Sir David Attenborough.



Attenborough's *Zoo Quest* team in 1955, planning their next venture to British Guiana

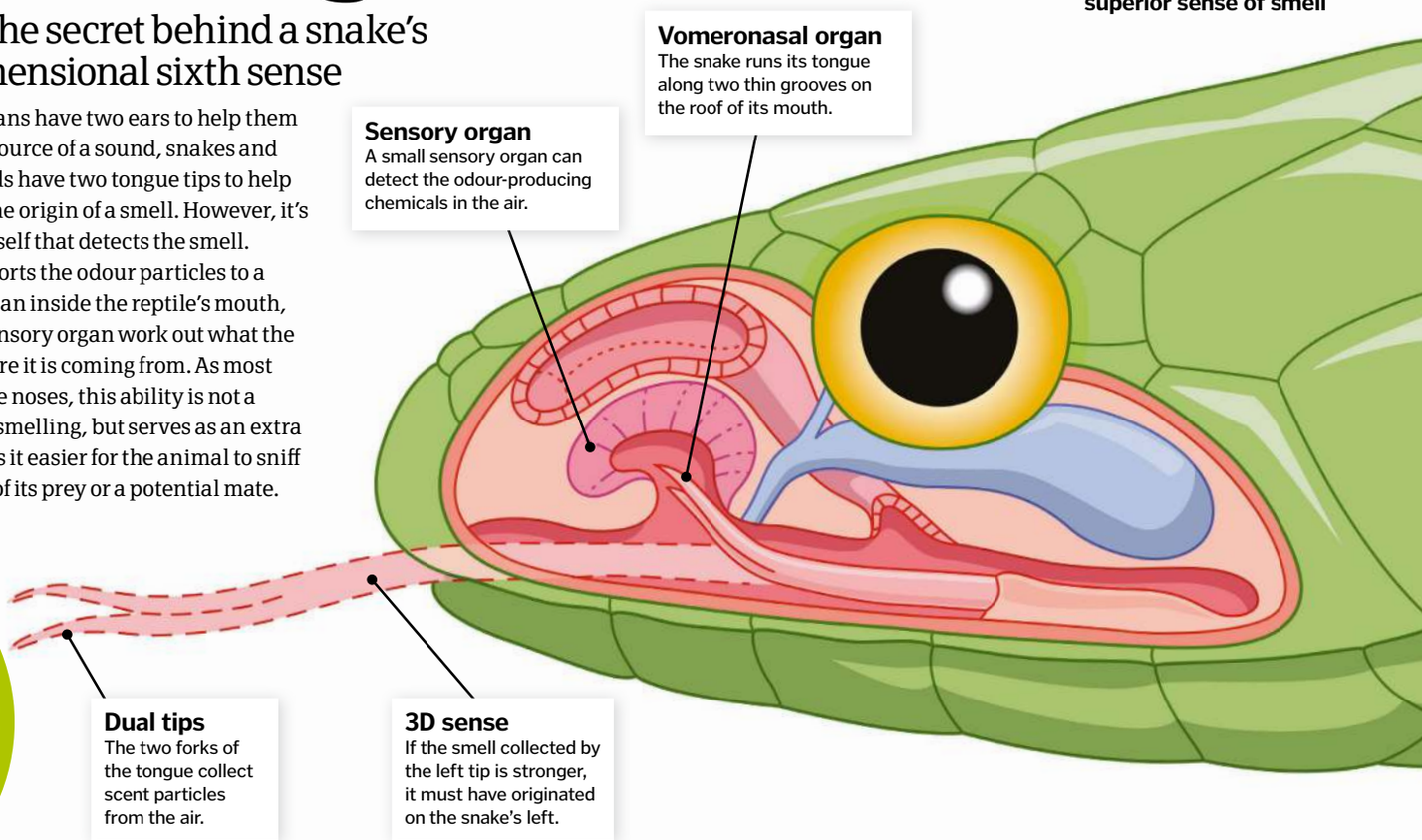
Forked tongues

Discover the secret behind a snake's three-dimensional sixth sense

Just as humans have two ears to help them locate the source of a sound, snakes and some lizards have two tongue tips to help them work out the origin of a smell. However, it's not the tongue itself that detects the smell. Instead it transports the odour particles to a vomeronasal organ inside the reptile's mouth, which helps a sensory organ work out what the smell is and where it is coming from. As most reptiles also have noses, this ability is not a replacement for smelling, but serves as an extra sense that makes it easier for the animal to sniff out the location of its prey or a potential mate.

Smelling like a snake

The anatomy that gives a snake its superior sense of smell



Whale beaching

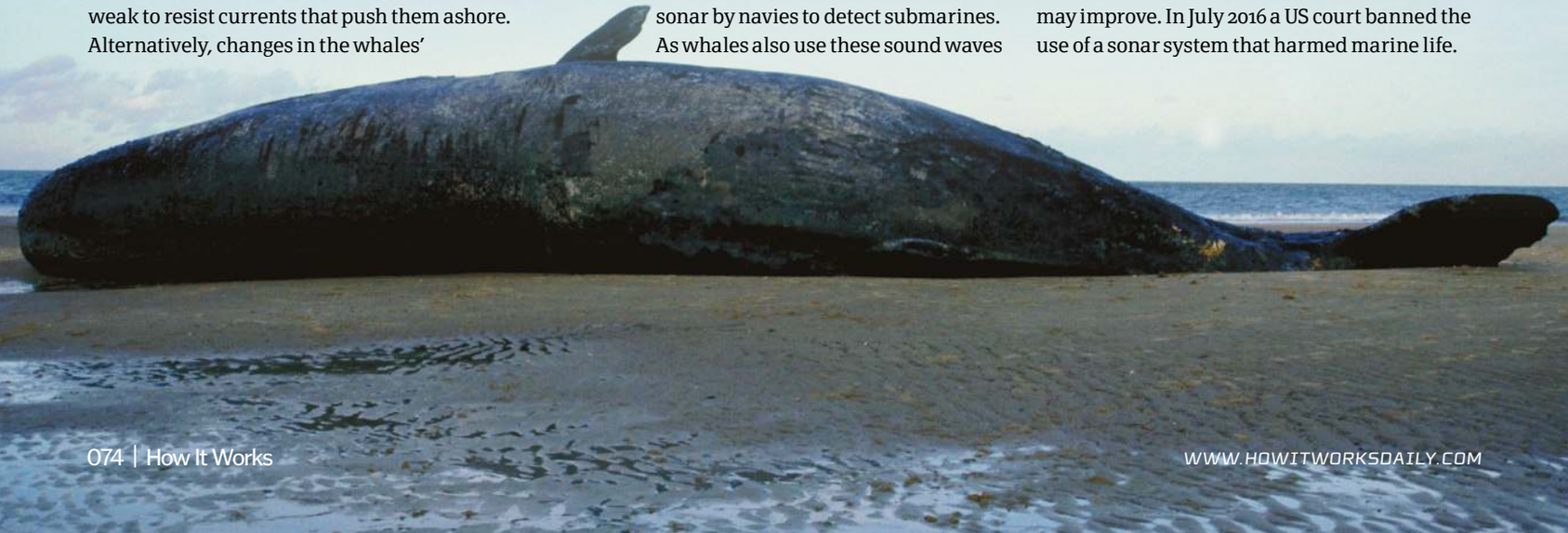
The mystery of why whales become stranded on the shore

Finding large groups of whales stuck on beaches is becoming a more common occurrence across the world. Experts don't have one clear reason to explain why, but they do have several theories.

It could just be that illness, injury, genetic mutation or even old age leaves the whales too weak to resist currents that push them ashore. Alternatively, changes in the whales' environment, such as bad weather, rising ocean temperatures or pollution could cause them to become lost, or they may simply follow prey into the shallows and become trapped by a low tide.

Another theory involves ship technology. In 2001 a study found a correlation between mass whale strandings and the use of underwater sonar by navies to detect submarines. As whales also use these sound waves to navigate, they could be causing them to become disorientated.

Very social animals , whales often travel in groups called pods, and it's likely that when one becomes stranded, the rest of its pod will naturally follow or perhaps try to come to its rescue, resulting in a mass beaching. But things may improve. In July 2016 a US court banned the use of a sonar system that harmed marine life.



Whales cannot survive out of the water for long, so beaching is very dangerous for them

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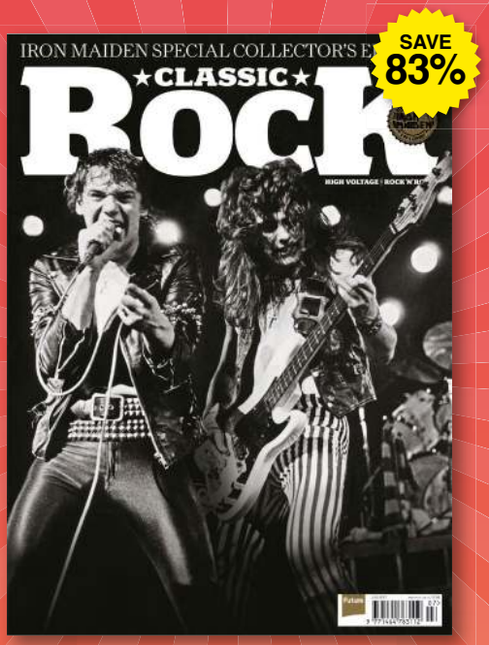

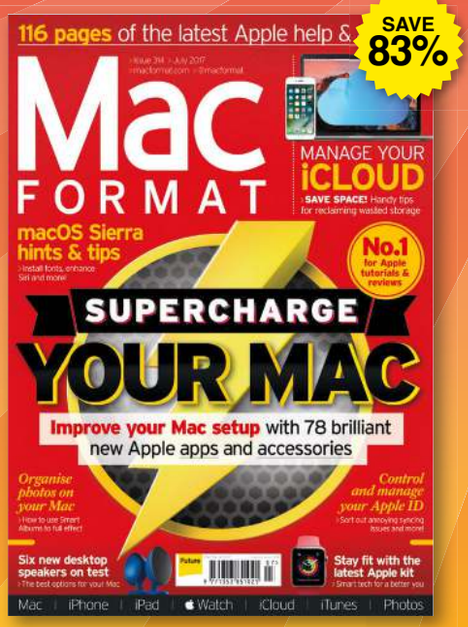

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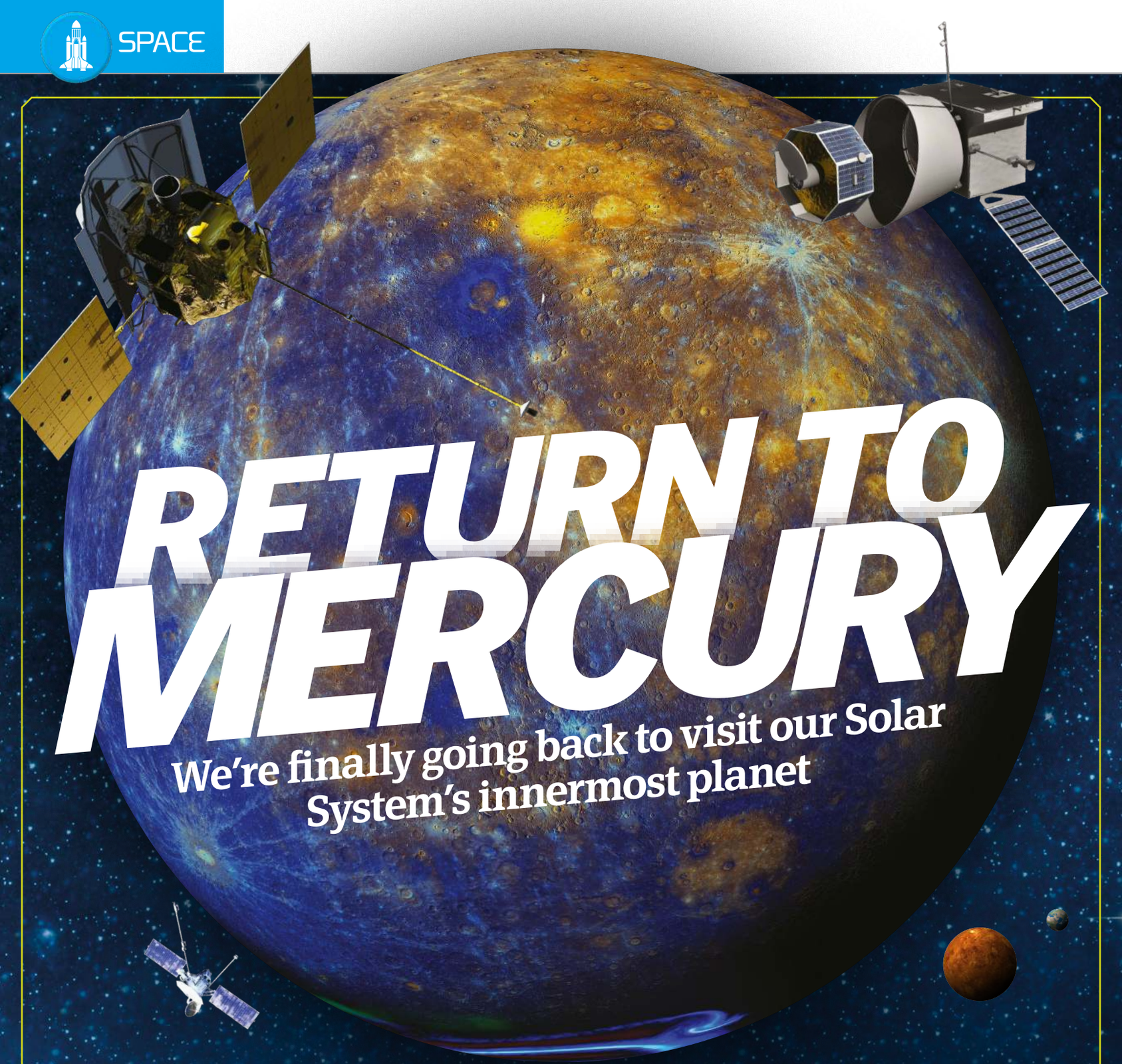


RETURN TO MERCURY

We're finally going back to visit our Solar System's innermost planet

At first glance, Mercury does not look too exciting. It's grey and barren like the Moon, with no noticeable atmosphere. But peer a bit closer and you'll find an intriguing world that is very exciting in its own right. And in 2018, a European-Japanese mission called BepiColombo will return to the closest planet to our Sun to investigate.

We've only ever sent two missions to Mercury, making it the least explored rocky planet in our Solar System. The first was NASA's Mariner 10 probe, which flew past the planet twice in 1974 and once in 1975. The next mission would not be for a generation, another NASA probe, this time called MESSENGER, which in 2011 became our first and only spacecraft to orbit Mercury.

Before the arrival of Mariner 10, very little was known about Mercury. We didn't know what the surface looked like, how it interacted with the Sun, whether it had an atmosphere, among several other key questions. Mariner 10 was able to map almost half of the planet's surface, taking more than 2,800 photos. It revealed a heavily cratered surface, similar to the Moon.

But it found some even more interesting information: it discovered that Mercury has an extremely thin atmosphere made of helium, and it also discovered the planet had a tiny magnetic field about 100-times weaker than Earth's. Now we're going back, with many unanswered questions still remaining.

For example, we don't fully understand how planets form so close to their star, or whether they move there at a later date. We also want to learn more about the interior of Mercury and find out what's generating its magnetic field.

Another area that scientists will be keen to explore are the permanently shadowed craters, inside which there may be ice that's kept hidden from the glare of the Sun. Often overlooked, Mercury is about to step out into the limelight once again.

The formation of Mercury

How we think this planet came into existence with the rest of our Solar System

Solar nebula
About 4.6 billion years ago, our Solar System begins to take shape from a disc of dust and gas known as a solar nebula.

Gas giants
The gas giants in our Solar System start to form first, just 10 million years after the Sun, carving out gaps in the discs of debris.

Rocky planets
A few million years later, rocky clumps are drawn together by gravity and form the terrestrial planets in the inner Solar System.

Protostar
The dust and gas at the centre of this solar nebula began to collapse under gravity, eventually forming our Sun.

Solar System
Over time, and thanks partially to Jupiter's gravity, the orbits of the planets in our Solar System including Mercury become stable.

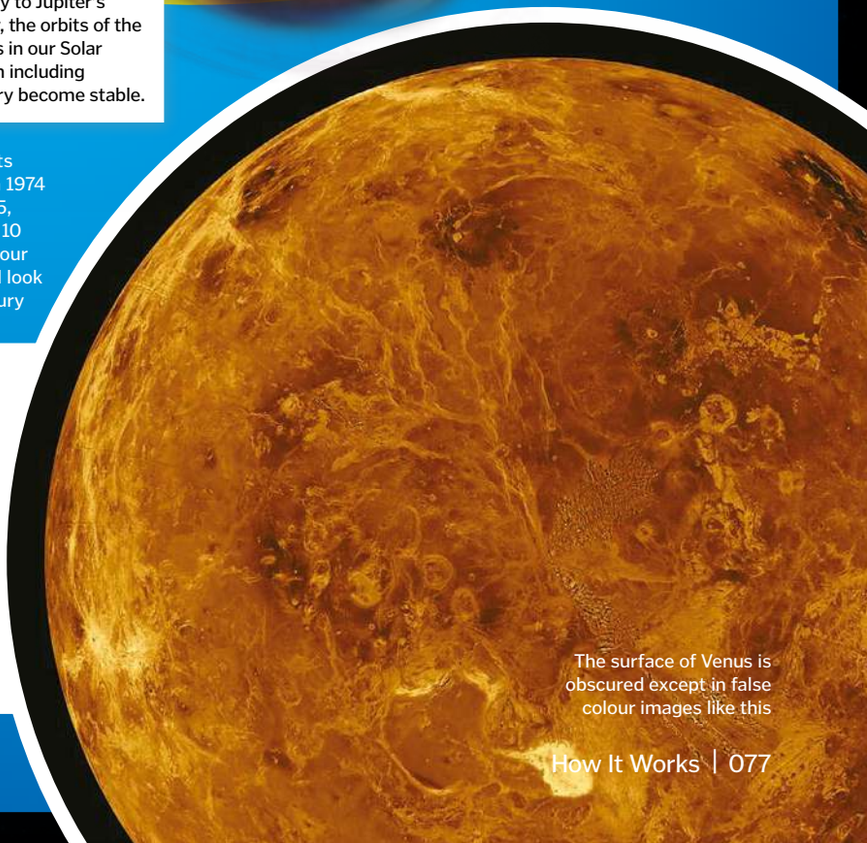
During its flybys in 1974 and 1975, Mariner 10 gave us our first real look at Mercury

Colder than Venus

Mercury is almost twice as close as Venus is to the Sun, so you'd think it would be hotter. But if you thought that, you'd be wrong. Venus has an average surface temperature of 460 degrees Celsius, whereas the temperature on Mercury ranges between -170 and +430 degrees Celsius.

The reason is due to Venus' thick atmosphere and the lack of one on Mercury. Owing to a runaway greenhouse effect, where carbon and water evaporated into the atmosphere of Venus, it went through a period of rapid warming. Today, it is a scorching world of such incredible heat that lead would melt on its surface.

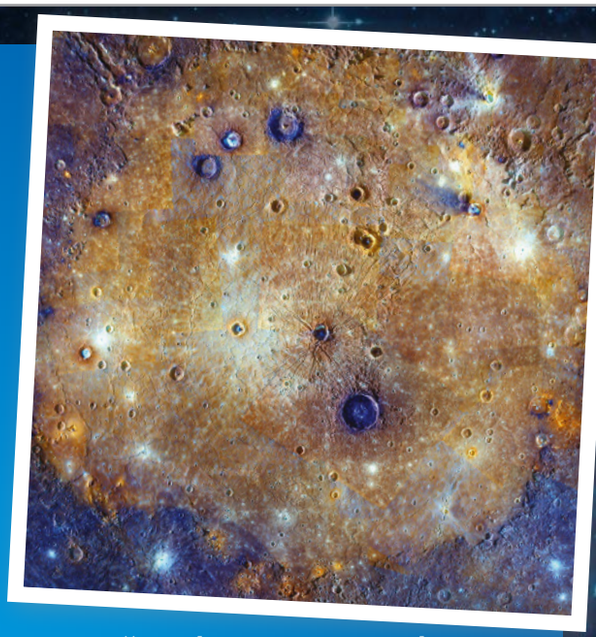
Mercury, on the other hand, has only a very thin atmosphere. This gives it huge temperature differences between its day side and night side, but it never reaches searing heat of Venus.



The surface of Venus is obscured except in false colour images like this

MESSENGER

How this mission brushed the Sun to enter orbit around Mercury



At 1,550 kilometres across, Mercury's Caloris Basin is one of the largest impact basins we know of

As Mercury orbits so close to the Sun, getting there is extremely difficult. Mariner 10 needed to fly past Venus, using its gravity to change its orientation, just to get the right trajectory to fly past Mercury. Entering orbit was a whole different business.

Many had thought it impossible to enter orbit around the planet without a huge amount of fuel. But using a novel manoeuvre, MESSENGER managed to do it. It launched on 2004, and what followed was a flyby of Earth, two of Venus and three of Mercury. It eventually entered orbit on 2011, a gruelling journey time of seven years. For comparison, it took New Horizons a relatively quick nine years to reach Pluto at the edge of the Solar System.

MESSENGER would prove hugely successful, though. Most importantly, it gave us our first ever global view of Mercury. This included views of the poles, where we think ice and possibly organic material might be hiding. Some estimates suggest it may have between 100 billion and 1 trillion tons of water in the form of ice, up to 20 metres deep in places.

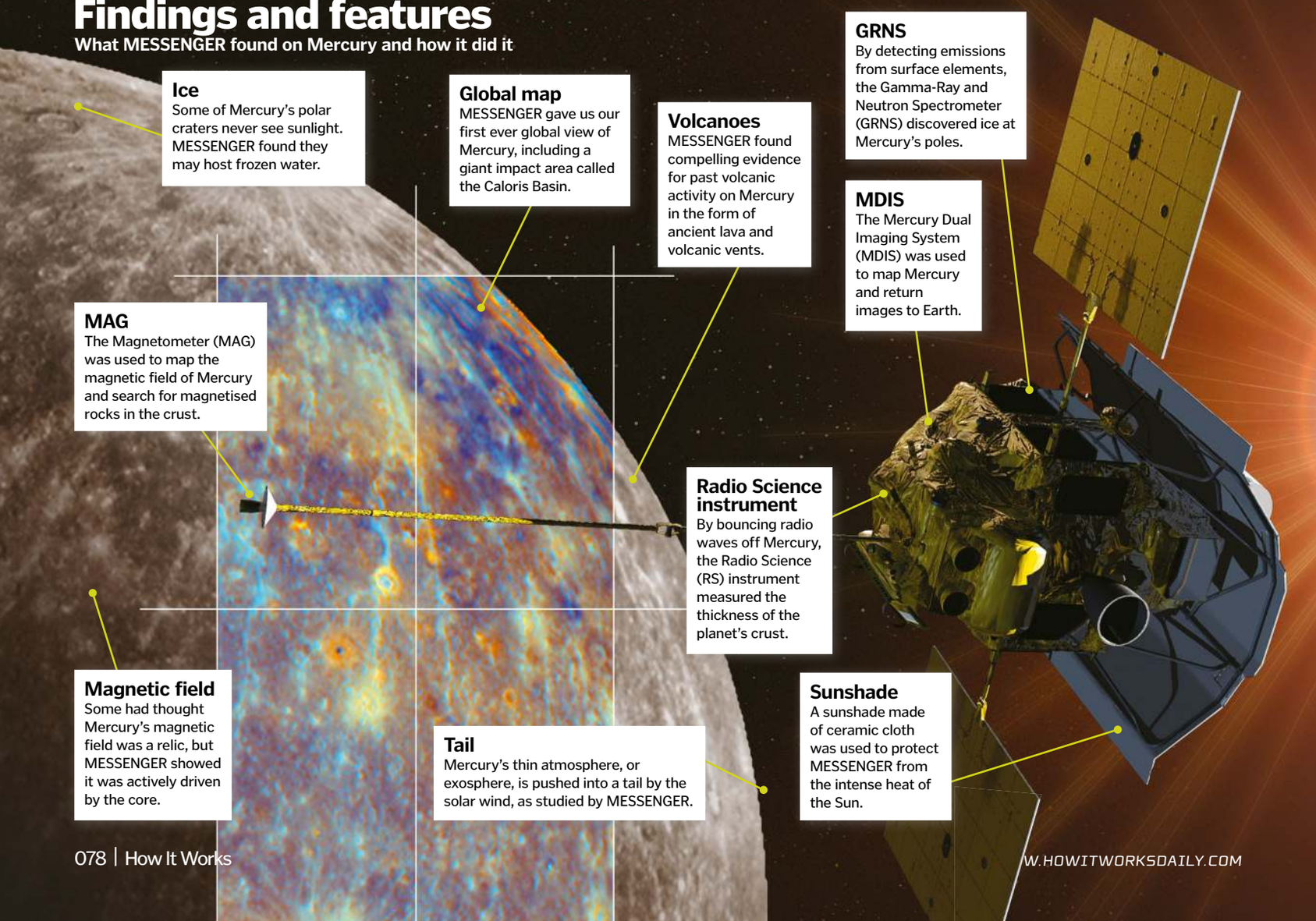
And this spacecraft also gave us fascinating new information about the core of Mercury. Scientists discovered its iron core made up 85 per cent of the radius of the planet, compared to Earth's core, which makes up only about half of our planet's radius.

On 30 April, 2015, MESSENGER was purposefully sent crashing into the surface of Mercury to bring its mission to an abrupt end. The only thing that remains of it now is a small crater in the northern hemisphere of our Sun's closest companion.

"Using a novel manoeuvre, MESSENGER managed to successfully enter Mercury's orbit"

Findings and features

What MESSENGER found on Mercury and how it did it



Ice
Some of Mercury's polar craters never see sunlight. MESSENGER found they may host frozen water.

Global map
MESSENGER gave us our first ever global view of Mercury, including a giant impact area called the Caloris Basin.

Volcanoes
MESSENGER found compelling evidence for past volcanic activity on Mercury in the form of ancient lava and volcanic vents.

GRNS
By detecting emissions from surface elements, the Gamma-Ray and Neutron Spectrometer (GRNS) discovered ice at Mercury's poles.

MDIS
The Mercury Dual Imaging System (MDIS) was used to map Mercury and return images to Earth.

MAG
The Magnetometer (MAG) was used to map the magnetic field of Mercury and search for magnetised rocks in the crust.

Radio Science instrument
By bouncing radio waves off Mercury, the Radio Science (RS) instrument measured the thickness of the planet's crust.

Magnetic field
Some had thought Mercury's magnetic field was a relic, but MESSENGER showed it was actively driven by the core.

Tail
Mercury's thin atmosphere, or exosphere, is pushed into a tail by the solar wind, as studied by MESSENGER.

Sunshade
A sunshade made of ceramic cloth was used to protect MESSENGER from the intense heat of the Sun.

The layers of Mercury

What's inside this weird and wonderful planet?

Outer core
Thanks to the MESSENGER mission we know that Mercury's outer core is liquid and not solid. By bouncing radio waves off Mercury, scientists deduced that wobbles in the planet's rotation were due to it having a liquid core.

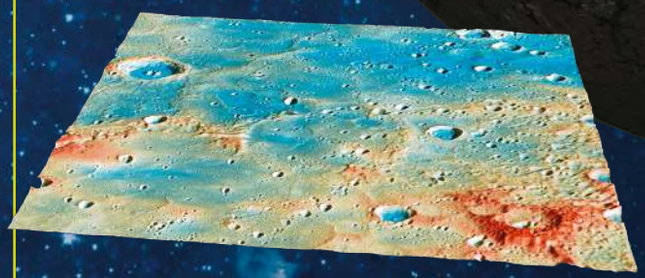
Crust
Earth has active plate tectonics on its surface, which means the appearance of our planet is constantly shifting. This is not so on Mercury, where its mostly static 100-300km-thick crust holds the scars of impacts past.

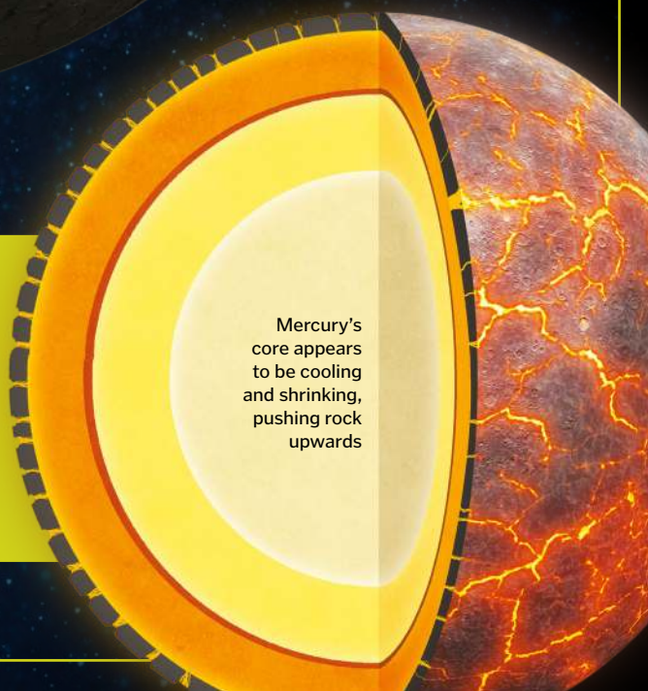
Inner core
At the centre of Mercury is a core comprised possibly of solid iron and other metals. The entire core, inner and outer, measures an astonishing 3,600km across, which is huge when compared to the 4,880km diameter of the planet.

Mantle
Just like Earth, Mercury also has a mantle that is composed of silicates. However, whereas the mantle on our world makes up most of our planet, on Mercury it accounts for as little as 500km of the planet's radius.

Surface
The surface of Mercury is a pockmarked world of craters, ridges and mountains. Its distant history of impacts is preserved, and some of the Solar System's earliest material may be present on the surface.

MESSENGER purposefully crashed into the surface near the Shakespeare impact basin (in the bottom left of the image below)





Mercury's core appears to be cooling and shrinking, pushing rock upwards

A shrinking world

Scientists had thought Mercury was a dead world devoid of any activity. MESSENGER changed all that when it discovered the planet was shrinking, making Mercury a somewhat tectonically active world like Earth, albeit without shifting plates like our planet.

Evidence for this comes from a number of sources, one of which is a 'great valley' on Mercury. It's 400 kilometres wide and three kilometres deep, and scientists think it was in part formed by the global contraction of the planet. The cause seems to be Mercury's cooling core. As it cools it pushes up some of the rocks in its mantle, thrusting them upwards into scarps. These cliff-like formations are seen in the valley.

This shrinkage is admittedly very small; it's estimated Mercury has shrunk about 14 kilometres since its formation. But that's still exciting for a world that once seemed lifeless.

BepiColombo

How this mission will reignite a lost love for Mercury

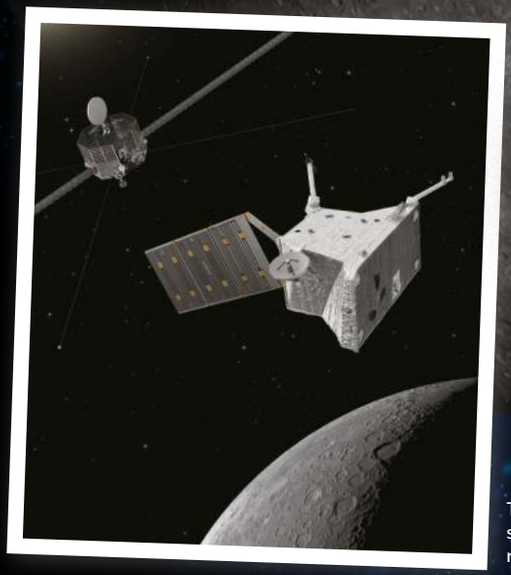
When the BepiColombo mission launches in October 2018 on an Ariane 5 rocket, it will have been more than three years since the MESSENGER spacecraft ended its mission at Mercury. But our return will be worth the wait.

Named after Italian scientist Giuseppe 'Bepi' Colombo, who was involved with Mariner 10, this mission has been in the planning stages since the turn of the century. It is a collaboration between Europe and Japan, who have each built an orbiter. The former is the Mercury Planet Orbiter (MPO), and the latter is the Mercury Magnetospheric Orbiter (MMO). Both will launch on a mothership, the European-built Mercury Transfer Module (MTM), to get to the planet.

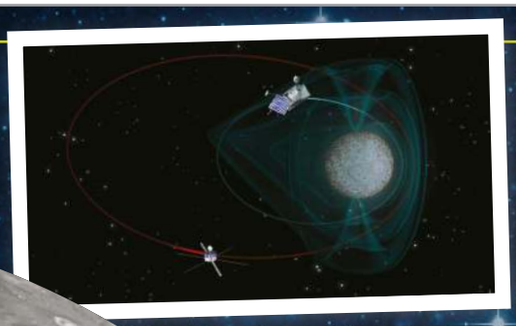
As was the case with MESSENGER, getting there will not be easy. The journey will involve a flyby of Earth, two of Venus, and six of Mercury before the two spacecraft enter orbit in December 2025 – more than a decade since we were last at Mercury. Once there, both spacecraft have a primary mission lasting about one Earth year, which is four Mercury years. If funding permits, this could be extended.

Even in that relatively short time, a whole host of science is planned. The two spacecraft will have different orbits around Mercury, during which they'll use their suites of instruments to study the atmosphere of Mercury, its magnetic field, and much more.

Mariner 10 may have given us a taste of Mercury, and MESSENGER more of a hearty meal. But BepiColombo promises to give us a veritable feast of information and solve many lingering questions we have about this world.



The two spacecraft will separate when they reach Mercury in 2025



The planned orbits of the European (blue) and Japanese (red) missions

Mysterious Mercury

What will BepiColombo hope to discover about the first planet from the Sun?

How did Mercury form?

Some lingering doubts remain about how planets formed. One theory is that one rock grows larger and larger as it sweeps up material. Another is that pebble-like chunks build up together over time. BepiColombo may give us an answer.

Is Mercury tectonically active?

We've seen tantalising evidence that Mercury is shrinking, suggesting it is somewhat tectonically active like Earth. BepiColombo will look for more evidence of this, such as the great valley seen by MESSENGER.

Does it have water ice?

The poles of Mercury may be hiding vast quantities of water ice. BepiColombo will look for signs of this, in addition to sulphur and maybe even organics, which might be remnants of the early Solar System.

Why does it have a magnetic field?

Mercury's magnetic field is a bit of a mystery. Venus and Mars have been unable to hang onto theirs, but somehow Mercury's has survived. Getting to the bottom of this could tell us a lot about planetary evolution.

Can it prove Einstein right?

One of Mercury's quirks is that it traces out a path in its orbit, explained by Einstein's theory of General Relativity, which suggests space-time is curved. This mission will try to test that theory even further.

"This mission has been in the planning stages since the turn of the century"

The quest for answers

How BepiColombo will uncover the secrets of Mercury

BELA
The MPO's BepiColombo Laser Altimeter (BELA) will measure the topography of the surface.

Mothership
The Mercury Transfer Module (MTM) will transfer the two orbiters to Mercury.

SIMBIO-SYS
This suite on the MPO will return high-resolution images of Mercury.

MPPE
The Mercury Plasma Particle Experiment (MPPE) on the MMO will study particles from the planet and the solar wind.

MGF
The MMO's Magnetic Field Investigation (MGF) will study Mercury's magnetic field.

Below, BepiColombo undergoes an acoustic test to make sure it can withstand noise during launch

Intensive tests are underway to ensure BepiColombo is ready for its mission

Mercury in numbers

1 OF 5 PLANETS THAT CAN BE SEEN WITH THE NAKED EYE

Mercury has 38 per cent of Earth's gravity

A YEAR ON MERCURY LASTS
88
EARTH DAYS

A DAY ON MERCURY LASTS
58
EARTH DAYS

57mn km
MERCURY'S DISTANCE TO THE SUN, THREE TIMES CLOSER THAN EARTH

IT'S THE SECOND DENSEST PLANET AFTER EARTH

Mercury and Venus are the only two planets without moons

4,880km
THE WIDTH OF MERCURY, OUR SYSTEM'S SMALLEST PLANET

IT HAS MORE CRATERS ON ITS SURFACE THAN ANY OTHER PLANET

KIC 8462852's rapid dimming may be caused by comets passing in front of the star

Mystery signals

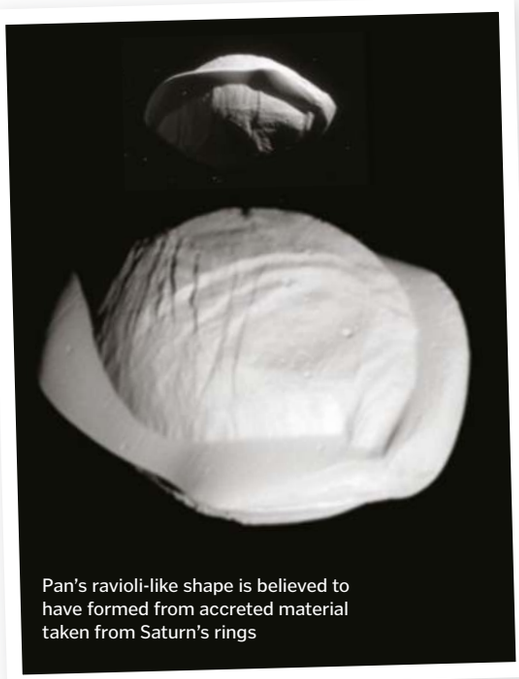
A distant star is acting strangely, and no one knows why

Almost 1,300 light years away, in the constellation of Cygnus, the star known informally as Tabby's Star shines brightly... well, some of the time at least.

Officially labelled as KIC 8462852, this star has become a bit of a celebrity among astronomers due to its erratic and drastic dimming periods. Researchers have so far been unable to predict these events and are mostly at a loss to explain how the star can lose over 20 per cent of its brightness in a matter of days before regaining its original brightness some time later.

There are plenty of theories to explain this phenomenon – including that of an alien megastructure assembled around the star to capture its solar energy – yet none are perfect. A previously popular idea stated that a swarm of passing comets may have temporarily obstructed the star's light from reaching us, but evidence of previous dimming events has cast this in doubt. A newer, planet-gobbling theory has since received growing support.

If Tabby's Star had partially devoured a planet in years past, the new material could have caused the star to brighten temporarily, and the remaining swirling debris could cause periods of dimming. But we haven't ruled out aliens yet.



Pan's ravioli-like shape is believed to have formed from accreted material taken from Saturn's rings

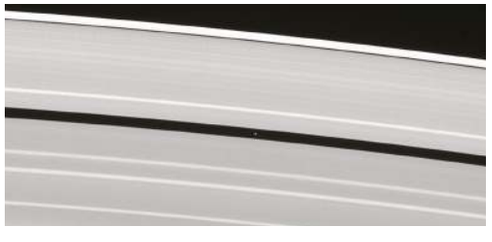
Pan

Drifting inside Saturn's rings is a distinctive little moon with an interesting story to tell

Saturn is a greedy planet. Not only does it boast the most developed and distinctive set of rings in the Solar System, but it also plays host to at least 53 moons! And from the ranks of these fascinating objects is a little moon orbiting a lonely lane between Saturn's A ring – known as the Encke Gap – featuring a rather unique peculiarity.

Enter Pan, a moon with a shape more akin to ravioli pasta than the spherical form we expect from orbiting satellites. Thanks to the Cassini mission we've been able to see Pan up close like never before, and scientists are starting to build a picture that explains this unique object.

The moon likely formed within Saturn's rings at a time when they were vertically thicker. The material within the rings began to accrete into a spherical clump, and after a time Pan had cleared the area around it, forming the Encke Gap. This didn't stop the little moon from gathering material from the rings, but due to its very weak gravity the new additions would simply settle and accumulate near it's equator, forming a distinctive narrow ridge of material.



By merging Hubble photos with images from ALMA, we can see more of the colliding galaxies than ever before

The Antenna Galaxies

What happens when two swirling masses of stars collide?

Around 100 million years ago, in the constellation of Corvus, two galaxies began to collide, and they will continue to merge for the next few billion years.

Once gliding calmly through space like our own galaxy, NGC 4038 and NGC 4039 are now in a violent stage of collision know as 'starburst', with huge amounts of new stars being made. Their nickname, the Antenna Galaxies, is derived from the long antenna-like 'arms' of gas and dust caused by the gravitational pull.

Though it is happening over 45 million light years away, the event can be photographed from Earth and then analysed. This photo combines ALMA images from the early testing phase and visible-light observations from the NASA/ESA Hubble Space Telescopes. The Hubble photos are the highest resolution that has ever been taken of the Antenna Galaxies. However, Hubble photos alone are limited, as clouds of gas shroud the dust and obstruct the view in visible light. That's where ALMA comes in. This array sits 5,000 metres above the Atacama Desert in Chile and can photograph at a much longer wavelength than we are able to see (0.3-3.6 millimetres), allowing us to peer through the obstructions and catch a first glimpse of the gases involved in a collision.

With the photos layered over one another it is possible to see both galaxies scattered with brilliant blue star-forming regions surrounded by glowing hydrogen gas (appearing in the image as pink or red). In these regions, clouds of gas are compressed under huge pressure, causing them to collapse under their own gravity and become a star.

Nearly half of the fainter objects are young clusters of thousands of stars, while the two large orange clouds to the left and right of the centre are the cores of the two galaxies, made up mostly of old stars. Currently 30,000 light years apart, in a few billion years the cores will have joined together to form a giant elliptical galaxy with a supermassive black hole at its heart.

How to pick a landing site

What are the criteria needed to touch down on another world?

Choosing where to land on another world is no mean feat. Some, like Venus, Mars and Titan, have considerable atmospheres that can help or hinder your spacecraft. Others, like the Moon and various comets, have no atmosphere at all – a challenge in its own right. And you've also got to make sure you get as much science out of the mission as you possibly can in order to justify all of the effort.

While there are different criteria for different worlds, the two basic goals are landing the spacecraft safely and getting the maximum science return. On Mars, as its atmosphere is not that thick, engineers often pluck for scientifically interesting locations near the equator. Aside from having more sunlight to power solar panels, these also have a thicker atmosphere, which the lander can use to slow down on its way to the surface.

It was a different story when the Huygens probe touched down in the southern hemisphere of Titan (Saturn's moon) in 2005, away from the equator. This was so the lander could stay in touch with its mothership, Cassini, to relay its data to Earth for the brief hour it would survive. The Russian Venera probes in the 1970s and 80s, meanwhile, all landed on a similar side of Venus, because this was the one that was pointing towards Earth when they touched down, so they could communicate.

Similarly, on the Comet 67P/Churyumov-Gerasimenko, the Philae probe touched down in 2014 in an area that kept it in contact with its mothership, Rosetta, but also had as few rocks as possible to provide a smooth landing – something that's important on other worlds, too.

Mars 2020 landing sites

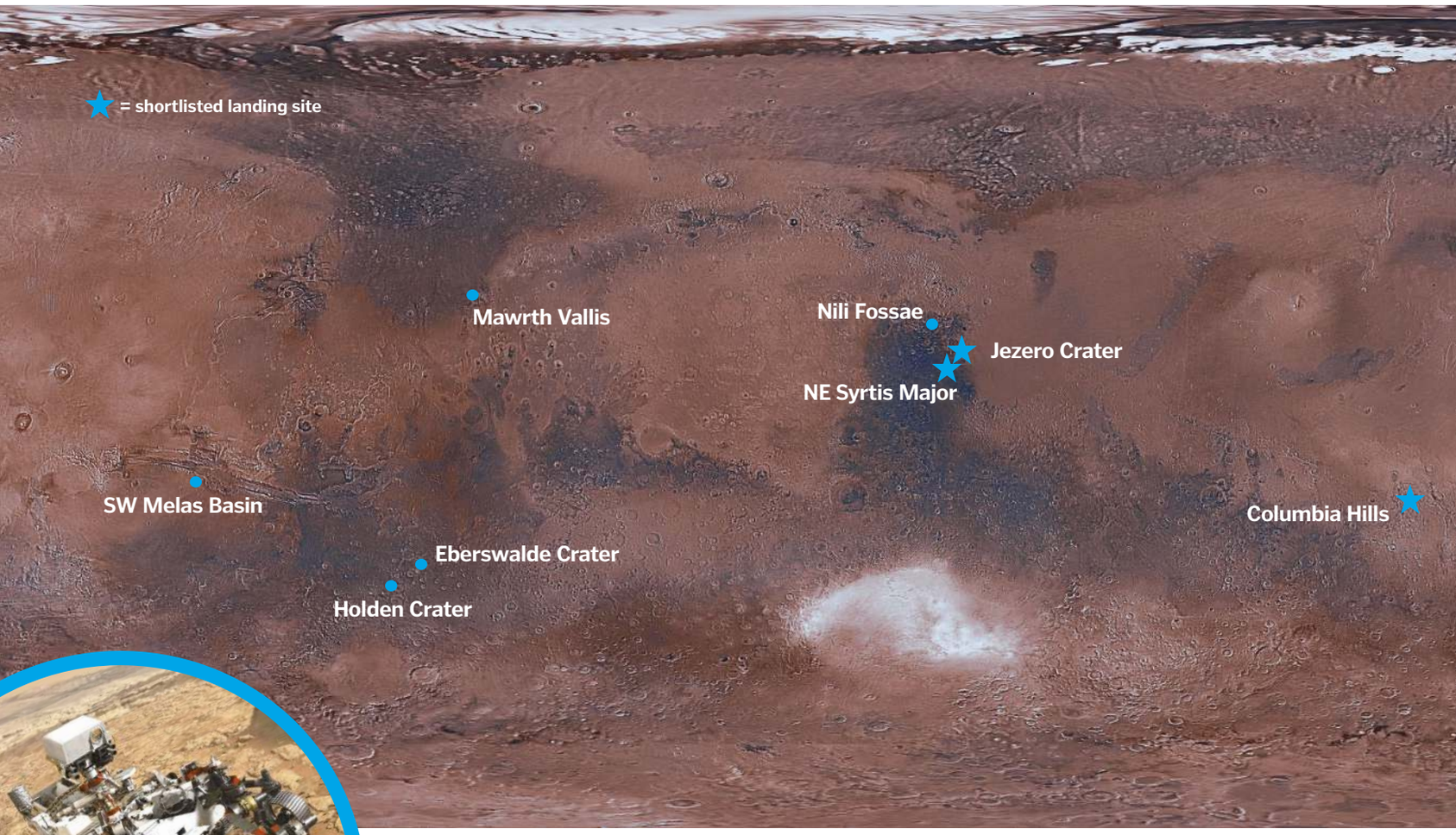
From a list of eight, NASA has shortlisted three locations for its next Mars rover

Mawrth Vallis
Signs of life could be preserved here in clay deposits that were excavated by a mysterious water channel coming out of the ground.

Nili Fossae
Shifted by tectonic faults, valleys here could have contained water. Methane has been found in this location, a potential signature of life on the Red Planet.

NE Syrtis Major
Past volcanic activity makes this an attractive location. Hot springs and melted ice in the area mean that microbes could have flourished here.

Jezero Crater
This crater is thought to contain the remains of an ancient lake dating back 3.5 billion years, complete with river channels and clay.



Holden Crater
A lake in this crater could have existed for thousands of years – long enough for life to thrive. Clays may still preserve signs of that life.

Eberswalde Crater
Containing a delta at the foot of a river, this location is interesting for having sediments deposited by water and protected from wind erosion.

SW Melas Basin
This basin once played host to a lake or delta, with volcanic ash also mixed in with clays that could have preserved signs of life.

Columbia Hills
The landing site for 2004's Spirit rover, this location is known to have signs of past habitability that could be re-explored in more detail.

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BRAIN DUMP

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MEET THE EXPERTS

Who's answering your questions this month?

Laura Mears

Laura studied biomedical science at King's College London and has a master's from Cambridge. She escaped the lab to pursue a career in science communication and also develops educational video games.

Alexandra Cheung

Having earned degrees from the University of Nottingham and Imperial College London, Alex has worked at many prestigious institutions, including CERN, London's Science Museum and the Institute of Physics.

Tom Lean

Tom is a historian of science at the British Library where he works on oral history projects. He recently published his first book, *Electronic Dreams: How 1980s Britain Learned To Love The Home Computer.*

Katy Sheen

Katy studied genetics at university and is a former **How It Works** team member. She now works for a biomedical journal, where she enjoys learning about the brilliant and bizarre science of the human body.

Joanna Stass

Having been a writer and editor for a number of years, **How It Works** alumnus Jo has picked up plenty of fascinating facts. She is particularly interested in natural world wonders, innovations in technology and adorable animals.

What happened to the Spirit rover?

Lilian Reed

The Spirit rover landed on Mars in 2004 to investigate rocks and soil. NASA expected its mission to last about 90 days but amazingly Spirit roved around Mars until 2009, when it got stuck in soft soil. Unable to move somewhere better for its solar panels to collect sunlight, Spirit was stuck for the Martian winter. Low power levels and low temperatures probably forced Spirit into hibernation mode or damaged it, and nothing has been heard from the rover since 2010. Spirit may be silent, but its twin, the Opportunity rover, is still active on Mars, an incredible 13 years longer than expected. **TL**

Who decides storm names?

Reese Fields

In the UK, members of the public can suggest storm names to the Met Office and Met Éireann. They then compile a list of 21 names beginning with each letter of the alphabet, excluding Q, U, X, Y and Z, and assign them to storms in alphabetical order, alternating between girls and boys names. For tropical storms such as hurricanes, the World Meteorological Organisation compiles its own list of names for each storm season and repeats them every six years. **JS**

What are barefoot shoes?

These shoes are designed to mimic being barefoot by offering minimal cushioning or support. The idea is to allow runners to feel as though they have no shoes on, whilst still providing some protection against stones, glass and tarmac. **LM**

Why is compressed air used on electronics?

Delicate electronics are easy to break if pressed or scratched. A jet of compressed air softly removes dust without you having to actually touch components, meaning there's less chance of damage. **TL**

What was the first hashtag on Twitter?

The first hashtag was #barcamp, relating to a technology conference. It was created in 2007 by Chris Messina, who tweeted to ask Twitter what they thought about using the # sign as a way of allowing groups to hold conversations more easily. Needless to say, the #idea quickly caught on. **TL**

Do other mammals go grey as they age?

Humans certainly aren't alone in this; gorillas, chimpanzees and dogs are all known to go grey in old age. Dogs can also go grey due to stress, just like their owners! However, giraffe spots change from brown to black with age, rather than taking on a silvery hue. **KS**

Can magnesium help you sleep?

Yolande Wright

Magnesium is thought to help people drift off thanks to its anti-anxiety and muscle relaxant properties. Magnesium is actually involved in hundreds of processes in your body, from bone health to nerve function, but its ability to help you sleep is not backed by science. Only a small number of trials have been run and these have only shown small benefits of taking magnesium for insomnia. While it is important that you have enough magnesium in your body, most people get their daily requirement from their diet, so taking supplements isn't always necessary. Green, leafy vegetables, nuts and seeds are all good sources of magnesium. **KS**

Australia is home to 170 species of land snake, but venomous bites are rare

What is the deadliest animal in Australia?

Ingrid Dervil

Australia is well known for its menagerie of poisonous snakes, spiders and sea creatures. So it might surprise you to know that between 2000 and 2013, the most deadly animals Down Under were horses, which were responsible for 74 deaths. Over the same time period, snakes caused 27 deaths and spiders didn't kill any humans at all. By comparison, snakebites are thought to cause around 45,000 deaths a year in India. **KS**

Which mountain is the most dangerous to climb?

Xiao Li

The Himalayan peak K2, also known as Savage Mountain, is considered the most deadly due to the brutally steep ascent. For every four climbers who reach the summit, one dies. **KS**

BRAIN DUMP

Right-handed scissors are designed so that a right-handed person can see what they are cutting

Why are there left- and right-handed scissors?

Valerie Carson

The arrangement of right-handed and left-handed scissors' blades takes into account the mechanics of the hand's grip to optimise cutting and allow the user to see what they're cutting clearly. When you use a pair of scissors, as well as a vertical motion your hand creates a lateral squeeze, with the thumb pushing slightly away from the palm. Right-handed scissors are engineered to harness this motion to push the blades together, but when used in the left hand, the blades are pushed apart. To create the same effect, left-handed scissors are a mirror image of right-handed ones. **AC**

Should ketchup be stored in the fridge or cupboard?

Alfie Stride

Most manufacturers advise that, once opened, ketchup should be stored in the fridge to maintain its freshness. However, due to the sugar and vinegar content of the condiment, it will still be safe to eat if it's kept in the cupboard for a time, but the taste or colour may alter slightly. Ketchup used to contain more salt, which meant it remained well preserved when stored in a cupboard. But with today's versions containing less salt, putting it in the fridge is now advised. **JS**

What was the first comic book?

It's thought to be *The Adventures of Mr Obadiah Oldbuck*, first published in Switzerland in 1837. Mr Oldbuck falls in love and faces trial after trial as he tries to win his love's heart. **LM**

Who was the first woman in space?

On 16 June, 1963, 26-year-old Soviet cosmonaut Valentina Tereshkova became the first woman to travel into space. She spent 71 hours piloting Vostok 6, orbiting Earth 48 times. **AC**

Is it true people can be born without fingerprints?

A handful of rare genetic conditions can cause someone to be born without fingerprints. In adermatoglyphia, a lack of fingerprints is the only symptom of a single gene mutation. Anomalies affecting skin, nails, hair, teeth and sweat glands can also cause this. **AC**

Why do your eyes water when it's windy outside?

Strong, cold wind blowing on your face can cause your eyes to become dry, so the lacrimal glands in your eyelids produce tears in order to keep them moist. **JS**

There's a scientific reason why headphones are so prone to tangling

Why do wires and cables tangle so easily?

Louis Moreau

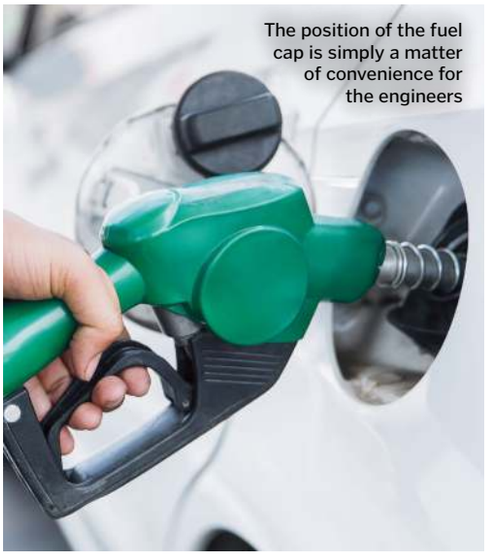
Imagine having a set of headphones in your pocket. As you walk along the headphone cables get jostled. This movement forms coils in the cable, braids them together and causes the loose ends to weave their way between the loops and strands, very quickly forming knots. In fact, scientists researching how wires get tangled discovered that it takes just a few seconds of jostling for knots to form and that longer cables tangle more easily. **TL**

There are 206 bones in the adult human body, most with Latin or Greek names

Where do the names of bones come from?

Mohamed Abasi

Most bones have Latin or Greek names, and many describe what they look like, where they are, or what they do. The bones in the inner ear are called the 'malleus', 'incus' and 'stapes', which mean hammer, anvil and stirrup. The word 'patella' (the kneecap) means shallow dish, while 'pelvis' means basin. 'Femur' means thigh, 'vertebra' comes from the Latin verb 'to turn', and 'mandible' from the Latin for 'to chew'. **LM**



The position of the fuel cap is simply a matter of convenience for the engineers

Water can cause phones to short-circuit, or corrode their metal components

How does rice fix a wet phone?

Kelly Tophill

Several studies have shown that burying a wet phone in rice is not the most effective method to dry it out. Rice readily absorbs moisture from the atmosphere, however, silica gel crystals have a much higher capacity to absorb water. But the most effective method to dry a water damaged phone is to open the casing up as much as possible and leave it in a dry, well-ventilated spot for up to 48 hours. **AC**

Why aren't all fuel caps on the same side of cars?

Milo Carlucci

As there are no laws stating which side of a car the fuel cap must be on, manufacturers are free to put it on whichever side they like. They usually make this decision based on the fuel tank design, location and underbody packaging, opting for the side that offers the easiest placement option. This can differ between car designs, so two models produced by the same manufacturer may each have the cap on different sides. Switching sides also has the added benefit of reducing congestion at fuel stations, as not everyone will have to queue for the same line of pumps. **JS**

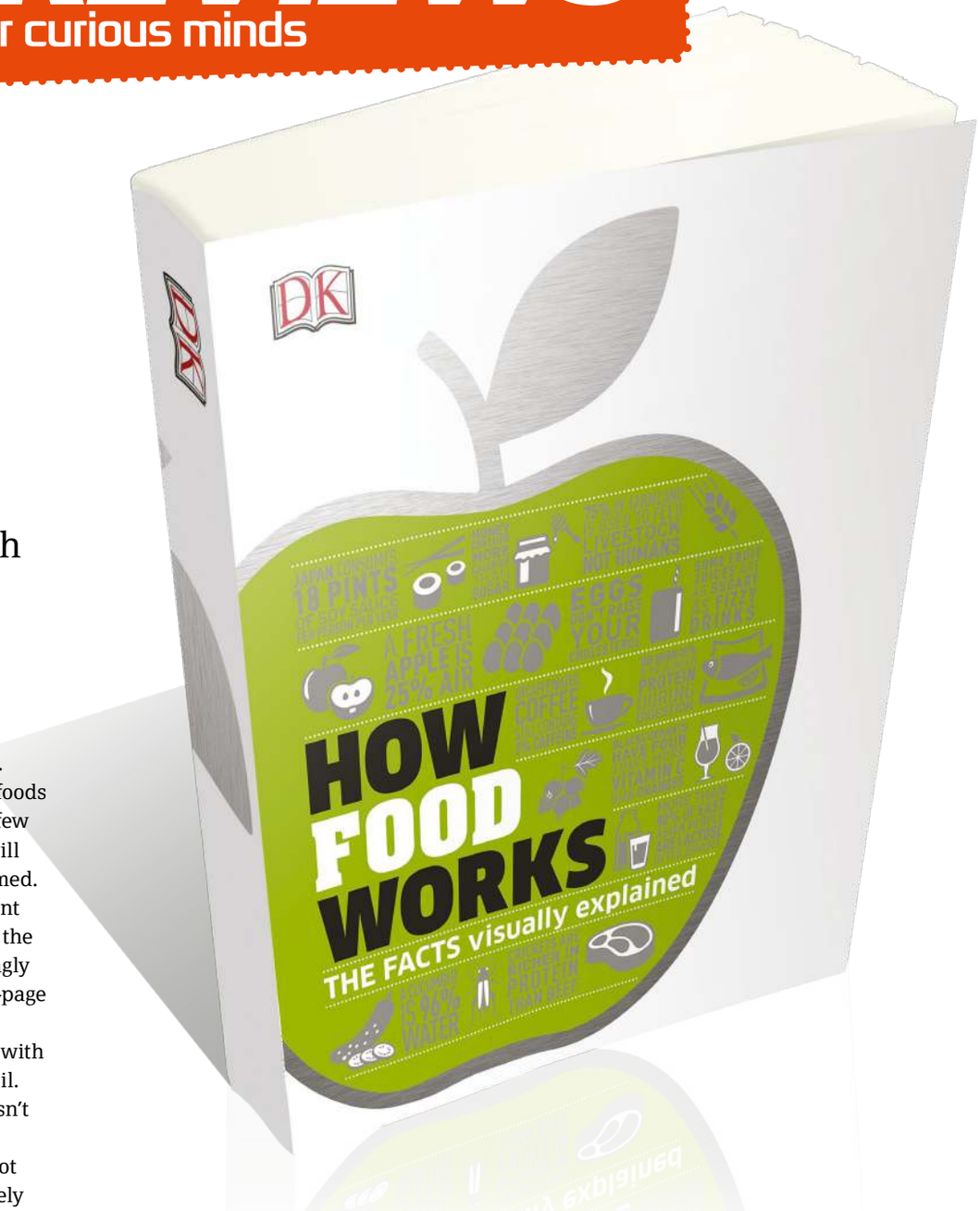
What happens to food that goes down the wrong way?

Dean Reader

Food can either go the right way down the oesophagus (food pipe) and into the stomach, or the wrong way, blocking the trachea (windpipe). If this happens, it triggers a rapid cough reflex; the lungs expel their air to try and force the food back up the way it came. Hitting someone on their back, between the shoulder blades, can also help to dislodge stuck food. If this fails, first aiders will often put their arms around someone's abdomen and pull in and up below the ribs; this is known as the Heimlich manoeuvre. It works by raising the pressure in the chest, forcing the food back out. **LM**

BOOK REVIEWS

The latest releases for curious minds



How Food Works

Learn facts about food with this fantastic visual guide

- Author: **Rob Houston (senior editor)**
- Publisher: **DK**
- Price: **£14.99 / $20**
- Release date: **Out now**

There are hundreds of myths and misunderstandings about food today. Whether you're wondering if certain foods are good or bad for you, or just looking for a few interesting facts about cooking, this book will surely keep you entertained and well informed.

Separated into chapters that cover different topics, *How Food Works* aims to break down the facts about food into what we would pleasingly describe as bite-sized chunks. Each double-page spread features one or more illustrations or diagrams to help explain a particular topic, with plenty of text to cover each one in more detail. The reading level here is fairly high so this isn't one for younger readers. But for those older readers with a thirst for knowledge (we're not even sorry about that one) there will definitely be something of interest here.

Some topics seem familiar at first glance, but the angle here is so focused on food that they're often covered in different ways. The 'Eggs' spread, for example, doesn't talk about how eggs are produced or what they are for. Instead it looks at the nutrients you'll find inside the yolk and why mixing and heating eggs in different ways gives different results. These sections are especially good as they make a topic that could have been dull much more interesting. The section on how to make the perfect cup of tea, and the one that explains how much caffeine is in different types of coffee, will both be interesting for children and adults alike.

The writing style is mostly very accessible and tailored to young teen readers, but it will appeal to adults as well thanks to the complex ideas and simple explanations. There are times where a little too much information is packed into a double-page spread – we would sometimes have liked another two pages on a certain topic, for example – but these issues are few and far between. For the most part, this is a well-designed and well-written book that will keep young scientists interestedly flicking through pages for a long time. It may even leave you hungry for more!

★★★★☆

YOU MAY ALSO LIKE...

Are You What You Eat?

Author: **N/A**
Publisher: **DK**
Price: **£9.98 / $16.99**
Release date: **Out now**

Aimed at a slightly younger reader, this fun book explores the role that food plays in the human body and covers all the main topics in an interesting and accessible way.

My First Human Body Book

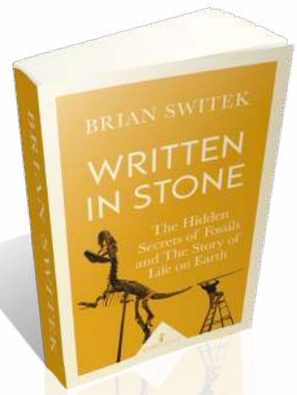
Author: **Patricia J Wynne**
Publisher: **Dover**
Price: **£2.99 (approx. $3.99)**
Release date: **Out now**

This colouring book is aimed at much younger audiences, and it is a great introduction to help children get into science and understand how food is processed by the body.

How The Body Works

Author: **N/A**
Publisher: **DK**
Price: **£14.99 / $20**
Release date: **Out now**

Find out what happens after food goes into your body in this biological book from the same collection as *How Food Works*. It's packed with information about the human body.



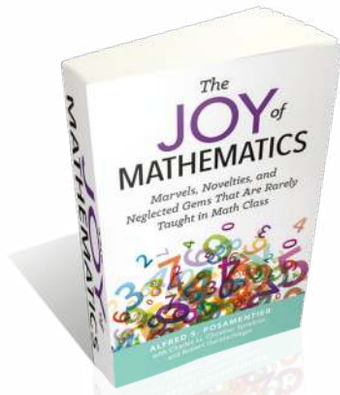
Written in Stone

Unearthing the hidden secrets of fossils

- Author: **Brian Switek**
- Publisher: **Icon Books UK**
- Price: **£8.99 (approx. $11.50)**
- Release date: **Out now**

The theory of evolution has reigned almost uncontested for generations, yet the physical evidence of our lineage remains incomplete. Within an engaging introductory chapter, author Brian Switek outlines the importance of rectifying these 'missing links' in the fossil record, and in the following chapters takes us on a journey from our distant ancestors to the anthropoids that walked the Earth just before homo sapiens. Switek has weaved an enjoyable narrative that is both excellently researched and easy to read, but scientific terms do feature often so some level of technical understanding is assumed. Heartily recommended for those wanting to dig deeper into the distant past.

★★★★★



The Joy Of Mathematics

Figuring it out

- Author: **Alfred S Posamentier**
- Publisher: **Prometheus Books**
- Price: **£25.99 / $18**
- Release date: **22 August**

Maths. We all have to study it, and not all of us enjoy it. The further in you get, the less clear-cut and more confounding things are – a perception *The Joy Of Mathematics* looks to challenge.

Ultimately, however, the results are mixed. While its aim is to show what's possible for the subject matter beyond the prescribed curriculum in schools, the end result isn't too far from your average textbook, only with fewer illustrations. The explanations contained within are sound but then you'd expect them to be. So if you're hoping to see maths demystified, then you will have to wait a bit longer.

★★★☆☆

30-Second London

Delve into the city

- Author: **Edward Denison (editor)**
- Publisher: **Ivy Press**
- Price: **£14.99 (approx. $19)**
- Release date: **Out now**

The latest piece of subject matter in the '30 Second' series is undoubtedly an ambitious one, attempting to cut down to size the background of one of the most historically rich cities on Earth. The result is something truly impressive.

From the capital's origins and geology all the way through its tumultuous evolution into the sprawling cityscape it is today, it's a genuine wonder how so much ground was covered. Many books aim to be for both adults and kids, but few actually achieve this feat. This book can rightfully claim to be an exception.

★★★★★

Rise Of The Machines

Explore the lost history of cybernetics

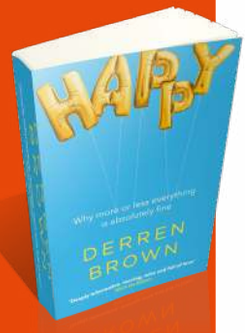
- Author: **Thomas Rid**
- Publisher: **Scribe UK**
- Price: **£9.99 (approx. $13)**
- Release date: **Out now**

No one can dispute the massive influence machines and the cyber world have on our daily lives. And yet the tale of our monumental transformation into a species reliant on cybernetics remains a mostly unexplored history, which is something that Thomas Rid's *Rise Of The Machines* aims to fix. With a story beginning in earnest in the 1940's and growing ever more prevalent in the following decades, Rid guides us expertly from an eccentric mathematician's idea to the advanced cyber world we live in today.

★★★★★

Happy

A look into our perception of happiness



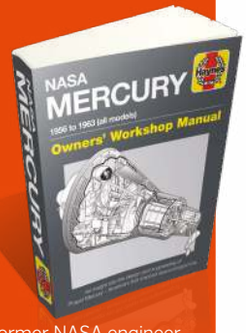
- Author: **Derren Brown**
- Publisher: **Bantam Press**
- Price: **£8.99 (approx. $12)**
- Release date: **Out now**

What does it mean to be happy? It's a question that was first posed over 2,000 years ago, but is the answer found in psychology or philosophy? In his fourth book, Derren Brown opts to blend the two disciplines together in a thought-provoking search for an answer. However, this isn't a self-help book but rather an exposure of the false truths that such books offer. Brown examines the often detrimental messages of self-help literature and challenges the reader to think further and deeper on the subject of true happiness.

★★★★½

NASA Mercury Owners' Workshop Manual

The engineering behind Project Mercury



- Author: **David Baker**
- Publisher: **Haynes**
- Price: **£22.99 / $36.95**
- Release date: **Out now**

If you're a space enthusiast there's little more exciting than the NASA space missions of the 1950s and 60s. Before Apollo there was Mercury, a programme of pioneering progress for the US space agency, displayed here in excellent detail. A former NASA engineer, Dr David Baker worked on the Gemini, Apollo and Shuttle programmes. In this manual his expertise are combined with in-depth illustrations and imagery to provide unmatched insight into Project Mercury. Highly recommended for those eager to delve into the missions that put the first US astronaut in space.

★★★★★

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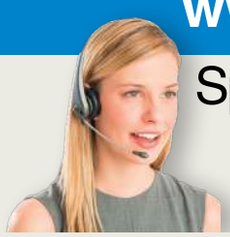

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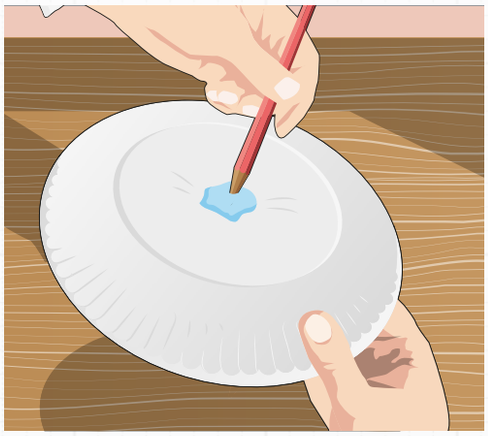
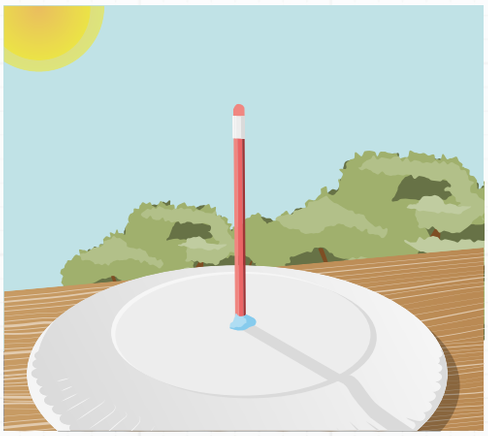
Make a working sundial

Track the time based on the position of the Sun

DON'T DO IT ALONE
IF YOU'RE UNDER 18, MAKE SURE YOU HAVE AN ADULT WITH YOU





1 Get set up

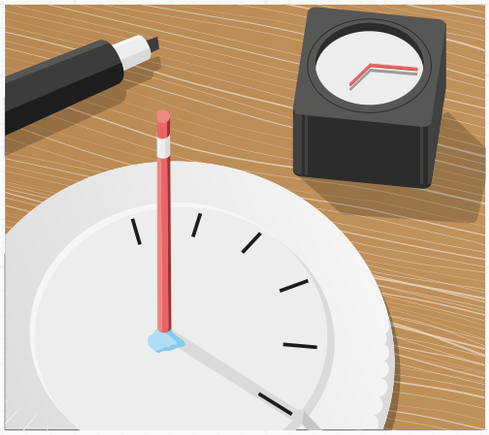
For this experiment you'll need a paper plate and a pencil. Push the pencil all the way through the paper plate, right in the centre. Put a ball of sticky tack on the plate over the hole and then push the pencil through the hole and into the sticky tack to secure it. Place the plate upside down outside or by a window, somewhere that will be in the sunshine all day.

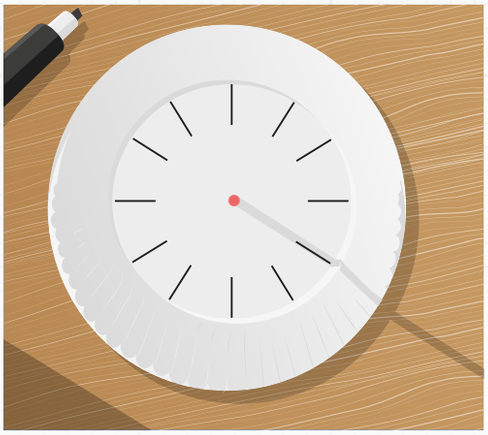
2 Get up early

To make your sundial, you'll need a watch or a clock to help you mark down the hours accurately. Once you've made it, though, the sundial will tell you the time! You'll need to start this experiment early in the morning to make sure you mark the first hour that the Sun appears. This time might change depending on the time of year, as the Sun rises earlier in the summer.

3 Make your dial

When your clock or watch shows that it's 7am, look at the sundial and put a dot on the paper plate where the shadow of the pencil falls. Once you've marked your first time you need to make sure that your sundial doesn't move, otherwise the times will all be wrong! Next to your 7am mark, write the number seven so you know the time it denotes.





4 Keep on marking

As the hours pass, keep marking the sundial on the hour and write a number next to it. What do you notice about the shadow as the day goes by? You might notice that as you approach midday the shadow gets shorter. That's because the Sun is higher in the sky, so the light shines almost straight downwards. As we move into the evening the shadow gets longer again.

5 Check the time

Once you have made your sundial you can use it to tell the time on sunny days. Even during the winter months, when the sunrise happens later in the morning, the times will still be the same on the sundial. You can check the shadow in order to see what time it is. Unfortunately, the only time that your sundial won't work is when it's a cloudy day and the Sun is blocked out.

> "Start early to mark the first hour that the Sun appears"

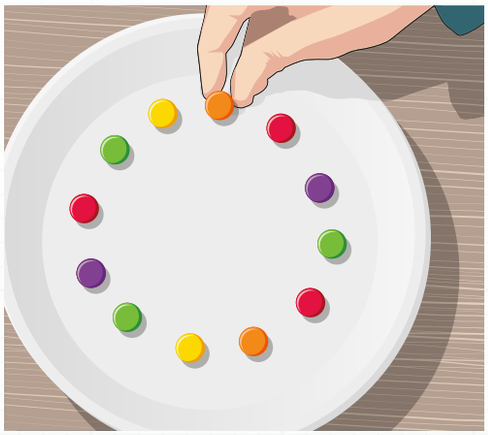
In summary...

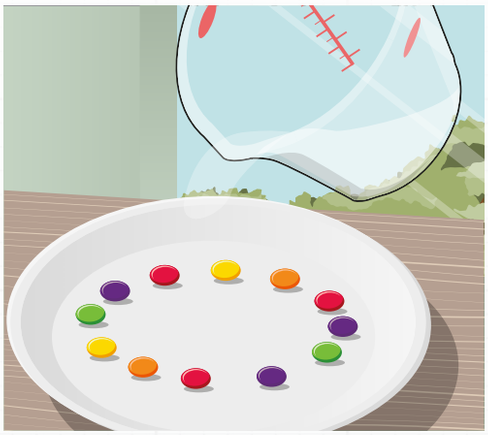
The shadow on the sundial is caused when the solid object blocks the light from the Sun. As the Sun appears to move across the sky, the shadow moves as well. Even though the Sun's path across the sky varies with the seasons, the rate at which it moves across the sky is the same every day. Sundials are very accurate for such a simple setup, which is why people used them to tell the time before mechanical clocks existed.

Make a rainbow with coloured sweets

Learn about the physics of diffusion using some tasty treats

NEXT ISSUE
TEST YOUR TASTEBUDS
MAKE A WORKING COMPASS





1 Prepare your rainbow

First, find a small flat plate – white plates work best to help you see the colours of the rainbow clearly. Find some colourful sweets, like Skittles, then separate them out so you have two of each colour. Place them evenly around the edge of your plate, and for the best effect, make sure that the same colours are opposite one another. You can also try mixing up the colours – where they meet you might get some interesting combinations.

2 Pour the water

Now you need to pour some water on your plate. Be careful not to pour too much or bump the plate as you pour, or the sweets might start to move and ruin your rainbow effect! Pour it carefully into the middle of the plate so that it spreads out to the edges slowly. You only need the water to be a millimetre or two deep, just enough so that it touches the sweets and can dissolve the colours in them.

3 Watch the rainbow

Depending on the kind of sweets you're using, the colours might start appearing in the water quite quickly. Wait and watch the plate as the particles in the water start to spread out. You'll notice they form triangular shapes pointing towards the centre of the plate. If you leave the plate for long enough the colours will start to mix! This is happening as the colour particles spread through the liquid after the water dissolves them.

"Depending on the sweets, the colours may appear quickly"

In summary...

The coloured sweets have food dye in them that dissolves in water. When the water touches it, the movement of the water molecules make the particles spread, or diffuse, through the liquid, and we can see them spread through the water thanks to their bright appearance.

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The Creoqode 2048's Arduino software enables you to create your own games.

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Where is the Chicxulub impact crater?

a) **Yucatán Peninsula, Mexico**

b) **Jurassic Coast, UK**

c) **The Moon**

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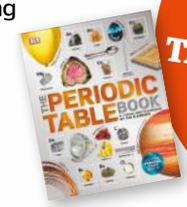

Magazine collections
We've loved your photos – please keep them coming!

Letter of the Month

92 not out

Dear **HIW**,
I'm a huge fan of your magazine and have had a subscription from issue 12 at the age of 7. I'm now 14 and I have got much inspiration and knowledge from your magazine. As of the 100th issue I will have 92 of them and have read each page with as much interest as the first. My favourite part of every magazine is the Global Eye. It puts the big news stories into an easy and understandable section, and I always look forward to each issue. Many of your articles have inspired my career choice to go into engineering, especially issue 59 with the main feature of racing cars.
I hope you carry on making such interesting and inspiring articles.
Yours sincerely,
David Thomas (aged 14)

Thank you for being such a dedicated reader, David. We feel honoured to have influenced your career choice, and we wish you the best of luck with the engineering!

Between issues

Dear **HIW**,
Here is a picture of me and my collection of 26 issues of **How It Works**. I started with number 73 and have been reading them ever since! My favourite issue is number 76, because I love the survival guide by John Wiseman.
Oliver O'Brien
(aged 10)

A great snap Oliver! We are so glad you are still enjoying HIW. The survival guide was one of our favourite features too!

Spelling it out

Hello **HIW** team
My name is Alexander Pereira. I am 12 and I love your magazine. I look forward to receiving your magazine in the post every month. Below, please find a photo showing my collection. This photo had to be taken outside as there were too many to fit in!
Alexander Pereira (aged 12)

Thanks Alexander, we are so glad that you look forward to each issue. What a great collection, and top marks for presentation!

What's happening on... social media?

We asked our followers why they chose to pursue a career in science...

"I was just so curious to find out how things work: cells, DNA... You never stop learning when you are in science. I switched careers though and became a high school teacher, encouraging young people to follow their hearts just like I did!"
Marja Miedema

"I love that there is always something to learn, and that there are new discoveries each day!"
Kara Turner

"I am actually back in school after 20 years; I switched my focus from film production to chemistry... It's a struggle, especially while working full time, but it's so worth it."
Leona A Morrissey

"Science just has so much for you to keep learning. When I was a kid I wanted to do so many different jobs. I'm 20 now and so lucky to have tried different types of science: plant molecular biology, human epidermal cell research and trial, and now veterinary science. It's all really satisfying, the different things you get to experience and all the new knowledge that keeps you fulfilled."
Ang Xue Yi

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Amazing trivia to blow your mind

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7.2M THE AMOUNT BY WHICH GREENLAND WOULD RAISE THE GLOBAL SEA LEVEL IF ALL OF ITS ICE MELTED

350 MILLION

THE NUMBER OF RUBIK'S CUBES THAT HAVE BEEN SOLD TO DATE

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IN THE YEAR

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A BLACK MAMBA SNAKE CAN REACH SPEEDS OF

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411,990KM

THE ESTIMATED DISTANCE TRAVELLED BY SIR DAVID ATTENBOROUGH FOR HIS *LIFE OF BIRDS* DOCUMENTARY

62

THE NUMBER OF MOONS ORBITING SATURN

8.8KM THE DISTANCE TRAVELLED BY THE FIRST HOT AIR BALLOON

687

THE NUMBER OF EARTH DAYS MARS TAKES TO ORBIT THE SUN

828,000KPH

THE AVERAGE SPEED OF OUR SOLAR SYSTEM AS IT TRAVELS THROUGH THE MILKY WAY

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- Telescope Focal Length 1200mm (f/8)
- Eyepieces Supplied 10mm & 25mm
- x2 Deluxe Barlow Lens
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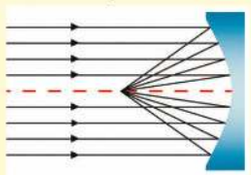

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PICK OF THE MONTH

Nex Machina

» **System:** PS4 (tested), PC » **Cost:** £15.99 » **Buy it from:** Online

Effortlessly riffing off *Robotron: 2084*, *Nex Machina* takes all the elements that have defined 35 years of twin-stick shooting and ramps everything up to 11. Its power-ups are meaty and incredibly satisfying to use, the level design throughout is exemplary, opening up new areas as waves of cleverly-placed enemies are disposed of, while each and every boss is a work of art, and it even makes sneaky nods to past classic games. And then there's the brilliant dash mechanic, an ability which has been ported across from *Resogun* and allows you to instantly cut through enemies and lasers in your search for stray humans (who boost your multiplier on collection). It dramatically alters the structure of your shooting: allowing you to effectively manage crowds of enemies, or navigate difficult terrain, but it can also land you in even more danger if you make a dash that's a little too desperate. It adds a sense of pace to an already speedy game and is one of the best examples of risk vs reward that we've recently encountered.

There's also endless potential for racking up high scores, thanks to the clever multiplier system and numerous difficulty modes that are available. *Nex Machina* certainly isn't easy (you'll need the 99 credits you're given on its standard difficulty) but it's never unfair and as you learn the levels and become accustomed to the hypnotic patterns you realise that it's all about creating as much space for yourself as possible, space that you can use to briefly recollect your thoughts and prepare yourself for the next punishing attack wave.

Brilliantly scaled, *Nex Machina* is the most thrilling, exhilarating shooter that we've ever played and it sets the benchmark by which all future examples of the genre will be judged – from its scintillating throbbing soundtrack and raucous sound effects, to its immensely satisfying multiplayer mode. While its roots are clearly in the past, it's undeniably modern and is filled with exceptional looking graphics and endless examples of creativity (outrunning a boulder being one of our favourite examples). It's the arcade shooter distilled down to its purest form. In short it's astonishing.

>> Score **100%**

» [PS4] The bosses are superb, each offering numerous attack patterns that need to be mastered.

» [PS4] That X will increase your multiplier. Pick up as many as you can to ensure the best possible score.

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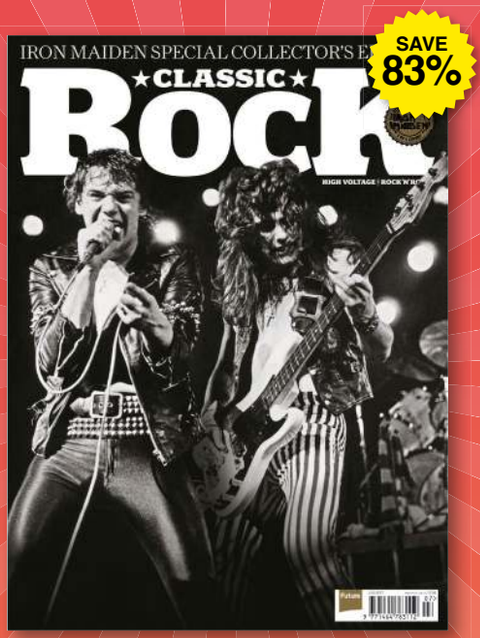

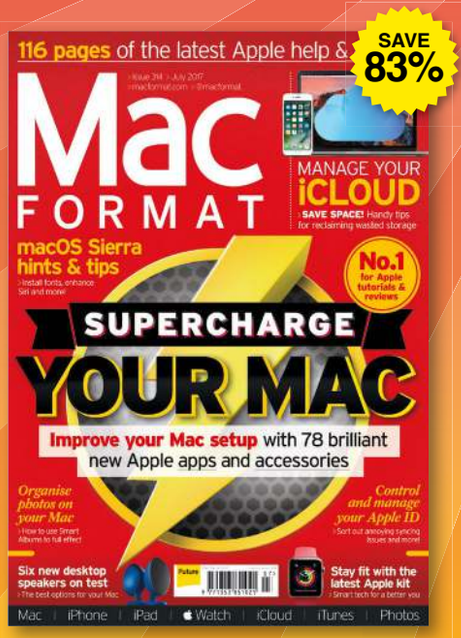

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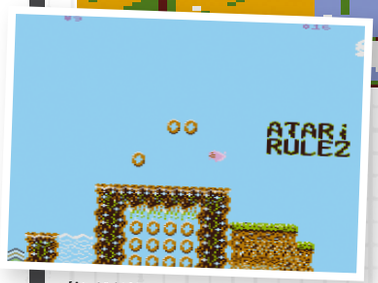
Gaming NEWS

» [Atari 8-bit] Coin collecting in an inhospitable landscape.



» [Atari 8-bit] Every cat deserves to be fed doughnuts if they want them.

» [Atari 8-bit] It might not be arcade perfect, but *Time Pilot* still manages to impress.

PLAYED ATARI TODAY

The Wap-niak party took place in Poland near the start of May and, along with some graphical entries and a cluster of musical remixes, the event's game competition is worthy of attention since it brought forth some very interesting entries. To begin with, there was the text adventure *Head Ache* which starts off simply enough in rather domestic surroundings with a man trying to deal with some pain, but soon takes a distressing, downwards turn. And staying with darker and more strategic titles for the moment, *Vox Regis* is in Polish, but, from what we gather, it's a game about making unpopular political decisions for the long-term good of the country.

Moving on to action-oriented titles, *Podskoczek* is a primitive-looking but interesting vertically-scrolling game where the player must ascend by jumping from platform to platform. The actual jumping is automated, so throw in a few special platforms that move or dissolve after being used a few times and making serious progress becomes trickier than it initially sounds. There's more platform action in *Hot & Cold Adventure*, although this time it's horizontal and sees a reptilian-looking creature make his way through some very nicely designed environments to collect coins while avoiding the patrolling enemies.

Crazy Cat is another platformer, but this time with multi-directional scrolling where the titular, pink feline wants to be fed a worryingly large quantity of doughnuts. Getting a cat to do something is usually difficult and, although it's under joystick control, keeping things heading in the right direction is a challenge due to a surprising turn of speed and some heavy inertia. Finally there is *Time Pilot*, a conversion of the classic arcade game which was the most impressive release; a few people have pointed out that it's not a perfect conversion of the arcade original, but we still enjoyed giving this one a quick blast and it even comes in standard and 65816 flavours for those with sped-up Atari 8-bits.

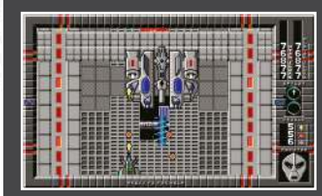
Overall, there was an interesting mixture of games offering quite a bit of variety, with even the three platformers being distinct in design from each other. Most of these games are considered to be works-in-progress so it'll be interesting to see final versions when they come out. Kikstart.eu/wapniak-2017 goes to the Atari Age forum thread where a link to all of the party's releases can be found.

Gaming REVIEWS

DO YOU REMEMBER?

After serving in World War 3, Major Harrison Stryker is given a new task by Fleet Admiral Yoshira, travelling by wormhole to take on the Kreton forces in their home territories using a brand-new, untested spaceship. There's a lot of enemy blasting to be done along with regular boss battles and the ship can be upgraded through icons from downed enemies.

Originally released for DOS PCs in 1993, *Major Stryker* is a challenging, vertically scrolling shoot-'em-up with brightly coloured EGA graphics, multiple layers of parallax scrolling and Adlib sound from Apogee, the same company who later published *Raptor: Call Of The Shadows*. It's available for free after signing up at 3D Realms' website behind Kikstart.eu/stryker-3drealms or with Steam integration for a couple of pounds at Kikstart.eu/stryker-steam.



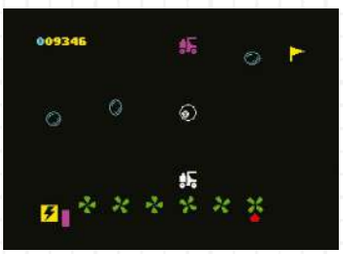
» [PC] This boss can be quite tough to defeat. Concentrate your fire to quickly destroy it.

» [PC] If it moves kill it. If it doesn't move, kill it anyway. It's the only way you can be really sure.

» [ZX Spectrum] Many defenceless bubbles were lost to these patrolling nasties.

JUBBLES

» **FORMAT:** SINCLAIR SPECTRUM » **DEVELOPER:** JONATHAN CAULDWELL » **DOWNLOAD:** KIKSTART.EU/JUBBLES-SPEC » **PRICE:** FREE



» [ZX Spectrum] Marshalling the bubbles as they float through the level.

» [ZX Spectrum] It's always a pleasant surprise to discover a new game from Jonathan Cauldwell.

The task set out by *Jubbles* is to guide bubbles as they drift from left to right across the screen so that they pop against the yellow flags and remove them from play. This proves to be easier said than done because the player can't control the bubbles directly; instead they float slowly downwards and there's a row of six electric fans at the bottom of the screen which can be used to blow air wherever the player sees fit.

The early stages are simple enough because they're all about getting the player used to operating the fans and how the bubbles react – they accelerate and decelerate vertically so the overall effect on the bubble will differ depending on which fan is used – but it doesn't take long before some of those targets become harder to hit, either, due to their positioning or because they've started moving. Further bubble-bursting obstacles, in the form of static and patrolling objects, arrive shortly afterwards so success on the later stages will require some thought and careful timing.

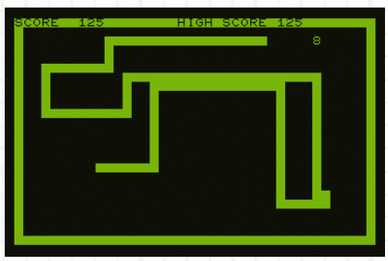
There isn't a time limit to keep an eye on and the bubbles will just keep coming indefinitely, so the only way to lose the game is to run out of the electricity which keeps the fans running and that's shown as a gauge to the left of the fans themselves. A bursting bonus stage pops up regularly where the player doesn't have to worry about dying as they try to take down as many bubbles as possible for extra score before the timer expires.

We haven't seen many new Spectrum games from Jonathan Cauldwell recently, mostly in part because he's been busy working away on *Arcade Game Designer*, so it was a pleasant surprise for us to receive an email about this one. The visuals are sparse, but functional, and the soundtrack on AY-equipped machines is excellent, but as with all of Jonathan's games it's the gameplay where this really stands out and the unusual control method will keep players busy for a while.

>> Score **91%**

PET SNAKE

» **FORMAT:** COMMODORE PET
» **DEVELOPER:** DONKEYSOFT » **PRICE:** FREE
» **DOWNLOAD:** KIKSTART.EU/SNAKE-PET



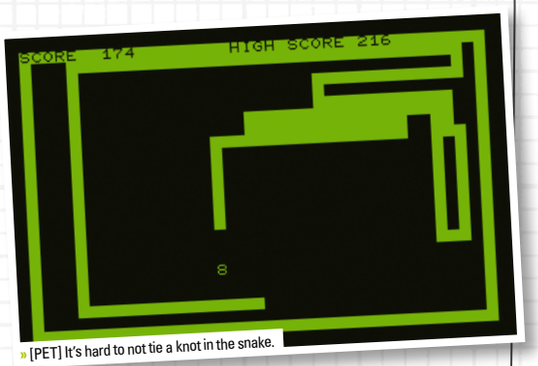
» [PET] Well, that's good news. *Snake* on Commodore PET.

***PET Snake* is, as might be suggested from the title, a version of the seminal *Snake* written for the Commodore PET, specifically a 16K machine with a 40-column display.** For those who have never owned a Nokia 3310, the titular reptile must gobble up tasty treats while avoiding its own tail which extends after each snack.

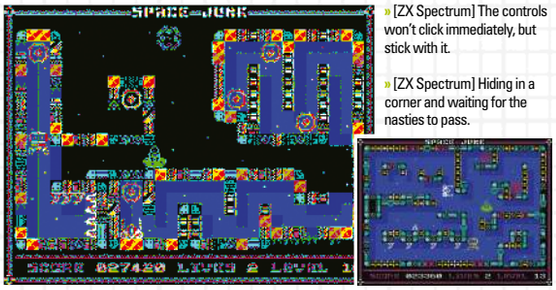
Those edible items are represented on the screen by numbers which will decrease over time. Grabbing large numbers is also a double-edged sword, since the value is added to both the score and tail length and further collection becomes even more difficult as the snake's own body starts getting in the way.

This version of *Snake* has the essentials to make it an entertaining challenge, but doesn't add any twists to the formula like some of the other recent variations on the theme like *Minesnake* for the Sharp MZ-80A have done which would have extended the longevity.

>> Score **73%**



» [PET] It's hard to not tie a knot in the snake.



» [ZX Spectrum] The controls won't click immediately, but stick with it.

» [ZX Spectrum] Hiding in a corner and waiting for the nasties to pass.

SPACE JUNK

» **FORMAT:** SINCLAIR SPECTRUM » **DEVELOPER:** MIGUETELO ART
» **PRICE:** FREE » **DOWNLOAD:** KIKSTART.EU/SPACE-JUNK-SPEC

Automated mining bases in the not-too-distant future that usually harvest resources for humanity have been hacked into, reprogrammed and essentially turned into Earth-destroying bombs. To prevent this catastrophe the player has to guide a craft around each mining facility, moving through some very confined spaces while destroying the generators and avoiding or, in some cases, stunning the now hostile support droids.

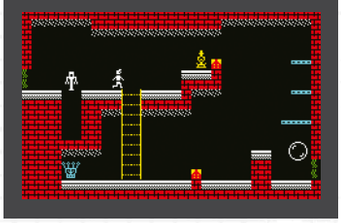
There is another problem to worry about, though, since the control system is more than a little quirky – selecting left, right, up or down is self-explanatory, but the direction the craft is currently facing and therefore firing is independent, based on current and previous input. This does make *Space Junk* frustrating, but after the penny drops those controls also make it stand out from other single-screen action games so players who want a little thought with their world-saving blasting should give this a try.

>> Score **81%**

ROUNDUP

How about a platform-based, archaeological quest to find and collect the legendary *Treasure Of Lumos* on the Spectrum? There are lots of dangers to be wary of, which will take some skill and timing to conquer because these adventures are never easy, but the riches to be gained if you're successful are worth it. Kikstart.eu/lumos-spec will locate a download.

There are more Spectrum-flavoured platforms in *Zabij Ducha* – which translates to English to 'Kill Ghost' – as well, but they constantly scroll and the player has to jump over the gaps to avoid plummeting to their doom while at the same time weaving between a couple of spectres as they float around. Kikstart.eu/ducha-spec heads over to the WOS forum discussion for more information.



EL TESORO PERDIDO DE CUAUTHEMOC

» **FORMAT:** AMSTRAD CPC » **DEVELOPER:** 4MHZ » **DOWNLOAD:** KIKSTART.EU/TESORO-PERDIDO-CPC » **PRICE:** FREE

It's time to raid a few tombs in search of riches, but also run into all manner of less-than-pleasant wildlife and other hazards along the way. The map initially seems quite small but those wily tomb builders have installed hidden buttons which need to be pushed to progress. And there's a few items which will come in handy as well, including bullets, dynamite and scuba gear – although who leaves these things lying around an ancient tomb without nicking all the treasures is anyone's guess.

Fans of *Rick Dangerous* will want to explore *El Tesoro Perdido De Cuauthemoc* because it has a similar feel to Core's game; the explorer is more hardy than Mr Dangerous and there are thankfully very few places where the safe path needs trial and error to discover. Overall, this is an excellent collect-'em-up with some superb graphics throughout and a solid soundtrack.

>> Score **92%**

» [Amstrad CPC] "Don't tell me truth hurts, little girl, 'cause it hurts like hell."

» [Amstrad CPC] How do I get to the useful-looking scuba diving kit?

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STAR LETTER

HANDHELD HEAVEN

Dear **Retro Gamer**,
First off, I'd like to say that I love your magazine. It's full of interesting features and I'm always impressed by the sheer amount of people you get to talk to every issue. Having said that, there is one area of the magazine that I feel you're rather weak on, namely handheld gaming, which has been a huge part of my life growing up.

I can't remember the last time you did a big behind-the-scenes look at a classic handheld game, which is quite disappointing as a long-time reader. I personally love handheld gaming and it's clear that many members of the team do as well, so why is there so little coverage in the magazine? I know we've had minority reports on many of the available handhelds, but it's not enough content for me and I'd love to see handheld classics like *Super Mario Land* and *GG Shinobi* getting their own standalone features. I've noticed the odd Game Boy Advance piece every now and then, which is much appreciated, but what I'd really love to see is big pieces on the PSP and Nintendo DS. One of them was the biggest-selling handheld of all time, so it's odd that it's had very little coverage in the magazine.
Jason Cooper

» [Game Boy] Simon feels games like *Super Mario Land* need more coverage. Do you agree?

Hi Jason. The main reason we don't cover handheld games as often as traditional releases is because of lack of access. There are lots of titles for which we'd love to do making ofs or ultimate guides, but we pride ourselves on our developer access first and foremost, and this can be quite tough if the games originated in Japan. There's nothing stopping us from doing smaller features, though, and we know Darran is itching to get more DS and PSP coverage into the magazine. Watch this space and have an eMag to read while you're waiting.

TWO-PAGE BLISS

I would just like to say I'm really liking the tight two-page spread format used with the recent *Chimera* article – issue 169. Like many of your 8-bit generation readership, and balancing a busy working and family life plus a love of retro gaming, it's good to see bite-size and accessible articles to fit the five minutes between walking the dog and getting the kids' dinner ready.

Although quite a subjective opinion, it really did fit the bill and was a great balance of facts, interview and anecdote, mixing well with the more expansive coverage throughout the issue.

What's next? Perhaps 'The history of *Manic Miner*' in a single tweet? Only joking by the way.

Keep up the good work Paul, Darran and team.
Martin Atkinson

Glad to hear you enjoy the format, Martin. We tend to do one of these every few months when a suitable game comes along, but maybe we could make them a more regular thing.

» [PC] An article about *Call Of Cthulhu: Dark Corners Of The Earth* will appear in a future issue of the issue.

CTHULHU QUERIES

Dear **Retro Gamer,**
Now that there is a new *Call Of Cthulhu* game coming out, I was wondering if you'd consider running an article on *Call Of Cthulhu: Dark Corners Of The Earth*, which was released on PC and console as an Xbox exclusive. It's a fantastic survival-horror game and one of my favourite Xbox releases. I'd be eternally grateful if you could feature it in the magazine in some way.
Mike Tooley

You're in luck, Mike: Darran is a big fan of the game himself and we've had a making-of planned for quite a few months. Expect to see a proper feature about it by the end of the year.

SHOOT TO THRILL

Hi Darran,
I have bought the magazine from issue one onwards and have a subscription. My heart belongs to the ZX Spectrum,

CONTACT US

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Future Publishing, Richmond House,
33 Richmond Hill, Bournemouth,
Dorset, BH2 6EZ
Email: darran.jones@futurenet.com

although I've had a dozen consoles since then. So, the gaming highlight of the last year has been *Project ZX* by Richard Langford. I have not seen a review and wonder if there are plans to cover this masterpiece? On a positive note, I loved the *Horace* piece recently and thought for a minute you were going to find William Tang!
Michael

We've not covered *Project ZX* in the magazine, but we are aware of it. We're aiming to get something together for a later issue, so watch this space.

NAME THAT GAME

Hi **Retro Gamer**,
I'm trying to find out the name of a game. I think it was on the C64. I'm afraid I don't have much to describe. Basically it was a platform game where it was a character, who I'm sure was holding a candle and navigating through a castle or mansion.

From what I remember (this was over 18 years ago), you had to search for car parts and build a car. There were two choices of car: a sports car, or a type of vintage car.

I'm sorry that's not much to go on. Thanks for any help you can give me.
Lee Wiseman

Worry not, Lee, for we know exactly which game you're talking about. It's *Olli & Lissa 3: The Candlelight Adventure,* which was coded by Simon Clarke and released in 1990. Hope it's as good as you remember.

VEGA WOES

Dear **Retro Gamer**,
Will the Vega Plus surface as predicted for its supposed summer release on the RCL page with the backers receiving theirs early, or will the ongoing legal turmoil delay it further? Only time will tell if it goes the same way as the Coleco Chameleon!
Cisko Kidd

It does seem like time is running out for the Vega Plus to hit its summer deadline. Needless to say, we'll be running a full story on the saga in a later issue of the magazine once all the problems surrounding it have been resolved.

DISCUSSED THIS MONTH

Darran's DS Collection

Not content with collecting original Xbox, Game Boy Advance and PS Vita games, Darran has now turned his attention to the DS. Originally content to collect both American and European titles, he had something of a crisis halfway through his collecting and suddenly decided he could only live with the uniformity of the American and Japanese releases. Who knows what he'll be collecting next issue…

» We last covered the Vega Plus in issue 153. A lot has happened since then…

From the forum

Every month, Retro Gamer asks a question on the forum and prints the best replies...

What's your favourite Commodore 64 game?

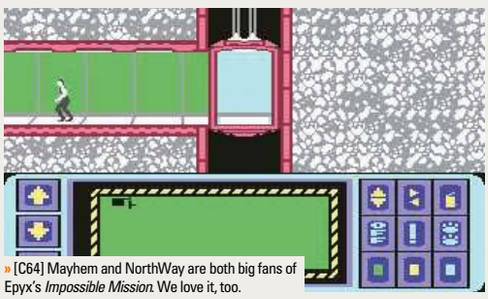
paranoid marvin
Enduro Racer and *Chase HQ*, because they showed how much better the Speccy was! *Buggy Boy* showed how a game could be translated from the arcade in a format that was perfect for far less powerful home machines. *Wizball* – unbelievable music, amazing graphics, fantastic gameplay – and pissed all over the 'superior' 16-bit machine's conversion.

Crusty Starfish
Entombed by Ultimate Play the Game. Chunky graphics but boy was that an atmospheric game! Also *Master of Magic* by Mastertronic, as it had that haunting and very long Hubbard soundtrack to draw you into a £1.99 bargain.

NorthWay
Impossible Mission, *Dropzone*. Lots of others.

fredghostmaster
Never owned a Commodore 64 but always looked forward to playing *Graham Gooch's Cricket* round my mate's house, after school.

RichL
Oh my word… *Ghosts n' Goblins* ('coz of the POKE I used to use to destroy all enemies on screen (POKE 4242,42 SYS 2128)). *Skool Daze* (I was still at school, come on – naming the teachers after my own). *Bubble Bobble* (I won a copy in a *Zzap!64* competition all those years ago). *Parallax* (that title music man…). *Delta* (ditto to *Parallax*!). *Wizball* (because!).



» [C64] Mayhem and NorthWay are both big fans of Epyx's *Impossible Mission*. We love it, too.

Mayhem
Impossible Mission, for pixel-perfect platforming par excellence. *IK+*, for triple-threat thumping chaos. And *Project Firestart*, for… well, seeing 'danger' written in blood within the first two minutes means the whole thing's gone to hell in a handcart very quickly. And you're in the middle of it.

kiwimike
Castle Wolfenstein and *Lode Runner*, along with a few Infocom adventures for me. When we had games nights, we used to play the likes of *Paperboy*, *Buggy Boy*, *DK'* and *Mario Brothers*.

mrmessy
Dropzone. I did not play it back in the day. I first played it about ten years ago. To me, it is THE stand-out game on the C64.

retro GAMER

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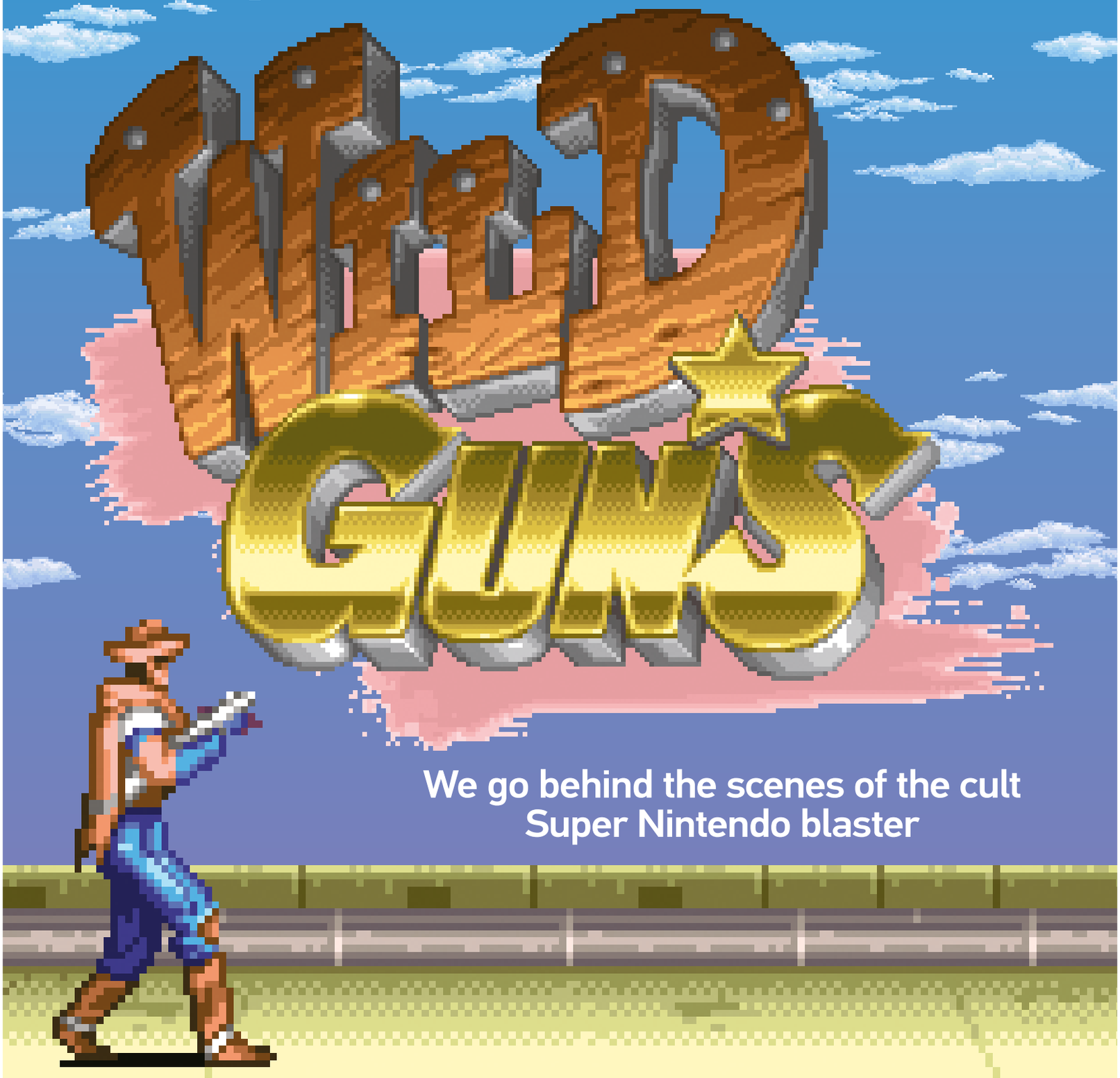

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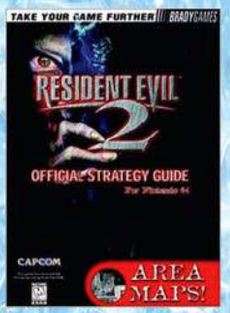

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